

KENTUCKY BLUEGRASS

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by

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This digest of selected literature, supplemented by recorded observations, is intended for in-Service use by forest officers, particularly in the central Rocky Mountain Region. Much of the material deals with inherent characteristics of bluegrass and may be applicable wherever bluegrass grows.

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INTRODUCTION

The place of Kentucky bluegrass, Poa pratensis L., in the flora of the western range has been debated with considerable fervor. This small ubiquitous grass has staunch champions who praise its high palatability, its ability to maintain itself under severe grazing and its soil-covering sod. Equally vehement are those who have noted that it is not a climax grass, that often it is not a high producer and that it becomes dormant when forage is most needed. Hereafter, the word "bluegrass" will refer to Kentucky bluegrass.

Large segments of the tall-grass prairie are in the process of conversion from prairie grasses to bluegrass. In the western mountain regions, bluegrass is abundant in the valleys, along creeks and small drainages, and in many cases, on drier flats and ridges where conditions are favorable to its growth. Here, it assumes importance on livestock ranges and on watersheds. Where grazing pressure is great, it often completely occupies bottoms after native grasses have been weakened or killed out. For this reason it furnishes forage in varying amounts in local areas where cattle normally concentrate and where they prefer to graze. Because of its site preferences, it is important where channel and gully erosion has occurred or may be expected to occur.

Most of the large amount of research on bluegrass has been done in the East. Also, intensive management is quite largely confined to the Corn Belt and Dairy States. As the demand for pasture becomes increasingly critical in the West, it is proper to assume that more intensive management of this grass will become necessary here. On the range, there are vital questions which must be answered: Where does bluegrass fit into plant succession? What are its growth and site requirements? Is it as productive, as dependable, and as desirable as native climax or sub-climax species? What systems of management and treatment are recommended.

With this in view, a resumé of important research is here presented. It may suggest methods of improved management, and it should develop a better understanding of this grass in western range and pasture management.

It has been necessary to screen the vast literature so that duplicating studies and researches not pertinent to this work were eliminated. Where the results obtained by two investigators were in conflict, it was necessary to consider their validity in the light of other related studies.

Since this summary is intended, primarily, for the administrative man, most references to the literature have been omitted from the text. There is included, however, a bibliography of the work from which source material was taken. The bibliography contains selected work only, since it was not intended to go into morphology, genetics, and similar studies. There is also an extensive European literature which is not included in the bibliography.

BLUEGRASS IN THE UNITED STATES

Poa pratensis, known as smooth meadow grass in England, and most commonly as Kentucky bluegrass or Junegrass in this country, is, without doubt, the world's most important single pasture grass. Throughout the dairy and stock-raising pastures of Europe and the northern United States it has come to be almost a universal component of the forage stands, alone or in mixture with clovers or other grasses, or as an invader in meadows.

Hughes* states that in southeastern Iowa, adjacent Missouri and Illinois, 50 percent of farm land is in permanent pasture. He further estimates that bluegrass constitutes fully 90 percent of the permanent grass cover of pastures in the Corn Belt. In southern Wisconsin about 45 percent of the farm land is in pasture, and bluegrass is the dominant grass throughout the area.

Lamson Scribner calls the Poas the blue-bloods of grasses, representing a primitive type of most ancient origin -- grasses which are pre-eminently builders of land.

Carrier and Bort reach the conclusion that Kentucky bluegrass is not native to North America. It was, with white clover, almost certainly introduced into Virginia and other very early coastal settlements where desirable forage grasses were lacking. This is not proof that bluegrass was not present in America. While it did not occur on the heavily wooded coast, it may have been growing in more favorable places farther inland. Bluegrass and white clover were well established in Kentucky when Daniel Boone explored that area. Carrier and Bort suggest that the French may have brought it to the Ohio River Valley. These authors state that botanists have not been able to trace the entry of bluegrass through Alaska and Labrador, along the ancestral migration routes of species of northern derivation which are native to North America as well as Europe and Asia. The Range Plant Handbook gives its range northward to Alaska and Labrador.

This does not explain its presence in nearly every mountain valley in the western United States where conditions are favorable to its growth. The first references to bluegrass in the Black Hills were made a few years after the first miners arrived and, apparently, it was not uncommon. Timothy, an undoubted introduction, which probably exceeds bluegrass in importance as a hay-grass, is more readily established from seed. Yet it is nowhere as universal in occurrence in the West as bluegrass, and where it is found, its origin and means of introduction can usually be accounted for.

Although its exact status in the North American flora may never be established, most authorities regard it as an introduced species.

* Complete titles appear after each author's name in the selected bibliography.

The literature indicates that prolonged, severe, and early grazing have been common practice in the bluegrass pastures of the United States. Many eastern and mid-western bluegrass pastures have come into being through destruction of woodlands by grazing. Misuse has been the result of carelessness and ignorance of the needs of this plant. Since one of the outstanding attributes of bluegrass is its ability to invade and persist under severe grazing pressure, it is not surprising that farmers and stockmen have accepted it as one of the bounties of nature and have given little heed to it so long as livestock were reasonably thrifty. Fortunately, a great deal of research has been done on this plant and its requirements are perhaps better understood now than those of any other grass. The necessity for proper management, and particularly the avoidance of excessively close grazing, have been abundantly demonstrated. It is to be hoped that such management will be universally practiced in time.

As a western forage plant, bluegrass has many excellent attributes. If it is possible to correct the widely prevalent destructive grazing and recognize the limitations and requirements of this plant, bluegrass will fill an important place on sites favorable to its development.

IDENTIFYING KENTUCKY BLUEGRASS

The bluegrasses, or Poas, are included in the Festuceae tribe of grasses. They are herbaceous plants with flat or folded leaves, boatshaped at the tip. The spikelets are small, perfect in most of the species, pedicillate (stalked) and in open panicles. They are two-to-many flowered, most often 3-5 flowered. The glumes and lemmas are always awnless and the glumes are shorter than the first floret. Lemmas are 5-nerved and keeled on the back, not rounded. The spikelets are not in one-sided dense clusters, and they are not strongly compressed.

Poa pratensis, Kentucky bluegrass, is a perennial with creeping rootstocks (rhizomes). The culm is not strongly flattened. Spikelets are 3-5 flowered. The lemmas are abundantly webbed with fine, silky white hairs, at the base. They are silky fuzzy (pubescent) on the lower half of the keel and marginal nerves. The panicle is pyramidal. The lowermost branches are usually in a whorl of 5, ascending or spreading, not reflexed.

THE BLUEGRASS SITE

Kentucky bluegrass finds optimum conditions for growth through a broad belt which includes, roughly, southern Canada and the northern half of the United States. At higher elevations its range extends well south of this line. In the Rocky Mountains it prefers the ponderosa pine and spruce-fir belts.

Temperature - The southern boundary of its natural range is limited principally by prevailing temperatures and particularly as these influence soil temperatures. Growth begins in early spring by rhizome extension when soil temperatures reach or exceed 32° F. Shortly thereafter it greens up but does not make much top growth until soil temperatures reach 50°. Throughout the bluegrass area, rate of growth reaches a natural

zenith when the soil attains a temperature range of 60° - 65° F. As temperatures increase above this optimum range growth declines and reaches a minimum when the soil becomes warmer than 80°. A lower peak of growth in late August or early September seems to correspond with seasonal decrease in soil temperatures.

Precipitation - Second only in importance to temperature is moisture, and particularly the distribution of precipitation. Average annual precipitation in the "Bluegrass Empire" varies from 32 inches in Iowa to 48 inches in Kentucky, with a generally prevailing average of 42 to 44 inches. However, the warm season precipitation - April to September, inclusive - has a relatively uniform average of about 22 inches throughout the area. Roughly, 60 percent of the rainfall comes during the six warm season months. While there are occasional summer droughts, distribution is fairly uniform at 3 inches to 4 inches per month. It would seem, then, that prevailing precipitation in the western range bluegrass areas, varying from 17 inches to 28 inches annually, would be entirely inadequate. A closer study of the Black Hills rainfall, as an example where bluegrass is especially important, reveals that about 70 percent, or 15 inches, of the 21.5 inch annual average comes during the warm season, and 6.8 inches fall in May and June during the zenith of bluegrass growth. At this critical time the amount of rainfall compares quite favorably with that of Iowa, Illinois and other bluegrass states.

On the Eastern Slope of Colorado with total precipitation of only about 18 inches, the peak also comes in May and June and again the amount is fairly favorable for bluegrass development. However, the common tendency toward drought in summer often interferes seriously with forage production and with maintenance of the sod. In 1949, with a severe winter followed by drought during July, August, and September, a series of study plots 50 miles northwest of Denver, suffered a 50% to 70% loss in bluegrass density. This loss was most severe on areas which had been closely grazed. In other plots, near Estes Park, where, under moderate use or complete protection, a blanket of organic mulch shielded the soil against excessive heat and moisture loss, no decreases in density were reported. As pointed out in a later section, the effects of grazing magnify the influences of precipitation and soil temperature and cannot be dissociated.

Another type of climate is that common to the Southwest where the precipitation peak usually occurs later in the summer. As an example, on the Western Slope of Colorado summer precipitation in the bluegrass zone is only about 11 inches, with a usual dry period from mid-May to July. Here bluegrass is a common grass in swales and flats, but it seldom produces much forage since the growth peak and precipitation peak do not correspond.

By correlating bluegrass occurrence with local precipitation patterns, it appears that bluegrass growth requires an average minimum of 16 inches annually, 10 to 11 inches warm season and 3 to 4 inches May-June precipitation. Below these minima, bluegrass probably occurs only where additional moisture is available from sub-irrigation or from runoff from adjacent slopes. (Fig. 3).

In any local evaluation of bluegrass as a forage grass it is, therefore, very important to consider the intensity, time and duration of these two important factors - temperature and precipitation.

Soils - Bluegrass prefers the finer textured soils, and is most frequently found on clays and fine loams. Its growth form permits it to persist on dense, compacted soils. It is seldom found on very sandy or gravelly soils. In the Nebraska Sandhills, it occasionally maintains a fair sod on the denser, more fertile soils in interdunal swales, but never ascends the dunes proper. Unless soil moisture conditions are very favorable, bluegrass seldom grows on long slopes of more than 20%. Bluegrass prefers bottom sites with high soil moisture, but will not grow on sites where the soil is saturated for extended periods. It is a common invader on bottoms which originally were marshy, but where erosion has lowered the water table and allowed the fertile, peaty soil to dry so that the site is moist but not saturated. Bluegrass seems to prefer soils which are neutral or slightly acid, that is, with pH values from 6 to 7. Although investigators have grown bluegrass successfully in nutrient solutions at pH 4.5 (very acid), an extensive survey in New York showed a pH range of 5.25 to 6.8 in a large series of bluegrass pastures.

On Crystal Creek near Paonia, Colorado, pH values of 6.5 to 6.7 (slightly acid) prevailed on three areas where bluegrass had been severely overgrazed. In the same locality, where bluegrass had complete protection for some 15 years, the pH value was 7.2 (approximately neutral).

Investigators agree that bluegrass requires high soil fertility and particularly high nitrogen content, although phosphates are also very important. Surveys in New York revealed that where Kentucky bluegrass colonies occurred in Canada bluegrass pastures, or where the reverse condition was true, the soil under Kentucky bluegrass invariably had higher nitrogen concentrations. Other investigators point to the fact that when bluegrass sod deteriorates, breaks up and becomes weedy, as a result of prolonged excessive grazing, low soil fertility is usually indicated, particularly a lack of nitrogen. Such pastures have been restored either by commercial or organic fertilizers or by planting legumes in the sod to restore fertility. Although there is, by no means, complete agreement, several investigators suggest that low production as a result of a "sod-bound" condition is the result of exhausted soil fertility and particularly lack of nitrogen.

Soil samples taken from overgrazed and protected bluegrass areas near Paonia, Colorado, by Schwan and Cramer, showed the following comparisons.

	Salts	Organic Matter	Nitrates (NO ₃)
Overgrazed (3 areas)	.02%	6.2%	5.5 p.p.m.
Protected 15 years	.13%	7.9%	12.7 p.p.m.

This analysis, while local and limited, indicates that overgrazing may be an important factor in reducing soil fertility under bluegrass sod. It should be noted, however, while organic matter and nitrates were decidedly lower in overgrazed areas than in the protected plot, they were still relatively high compared with average crop land.

Whitt reports that in Missouri on a plot which had grown cultivated crops for 35 years, bluegrass was established and during the following 8 years increased the nitrogen content of the 7 surface inches of soil 820 pounds per acre, or about 100 pounds per acre per annum. During the same period, organic matter increased approximately 1500 pounds per acre per annum. The decomposition of organic matter resulted in the release of minerals and in bringing nutrients like calcium into solution. Calcium, important in non-symbiotic nitrogen fixation, increased at the equivalent of 3500 pounds of limestone per acre during the 8 years.

Light - Very little investigative work has been done on the relative light requirements of bluegrass. Investigators agree that bluegrass is intolerant of dense shade. There seems to be agreement that the shading by tall vegetation is one factor in reducing bluegrass density on the prairie when protection from grazing allows this to occur. Under western conditions bluegrass frequently forms a good sod under the shade of moderately open aspen stands where taller competing and shading native herbs have been grazed out. In heavy shade under conifers, bluegrass fails to flourish, although there is observational evidence that fallen needles may have a toxic effect.

Detailed experiments have shown that failure of bluegrass to make growth in October, under temperature and moisture conditions very similar to those prevailing during the period of most rapid growth in May, can be accounted for by the length of day which is $2\frac{1}{2}$ to 3 hours less in October than in May. Thus, no method of fertilizing or irrigating could overcome the effect of short daylight periods and could not importantly increase rate of growth at this season.

ENEMIES OF BLUEGRASS

In eastern pastures various pathogenes, as rusts and mildews, attack bluegrass. In the West these are rare, usually local, and of small consequence.

A number of insect enemies may become locally important. Japanese beetles and cutworms cause trouble. Under range or pasture conditions the white-grub, larva of the June beetle (Phyllophaga) may be very destructive. In Wisconsin many pastures had suffered from prolonged excessively early and severe grazing. The weakened, deteriorated bluegrass sod provided an ideal habitat for egg-laying and larval development. Populations of white-grubs built up to $2\frac{1}{2}$ to $3\frac{1}{2}$ per square foot. A series of pastures were renovated by scarifying and planting legumes, accompanied in some cases by subsequent liming and application of fertilizers. Under the influence of such treatment, plus greatly improved grazing management, weeds were eliminated and the sod became dense and vigorous. White-grub populations were reduced 80% to 99% in from two to seven years. Repeated heavy flights of June beetles failed to reinfest these pastures.

Two destructive bugs, Miris dolabratus and Amblytylus nasutus, have been studied in the eastern states. These bugs lay their eggs by puncturing the culm, usually in the lower portions of the inflorescence. The larvae develop in the hollow stem and cause the panicle to die. The bugs feed on the bluegrass plants as well as on the seeds and flowers. They frequently greatly reduce seed crops and are a factor in commercial seed production.

The grasshopper is a destructive bluegrass enemy in the West. Where infestations are severe, grasshoppers may locally completely destroy the photosynthetic surface. Thus, these insects may be responsible for opening the sod and aiding the establishment of weedy plants.

Pocket gophers frequently burrow through bluegrass sod. It has been observed that forbs become established on gopher mounds and the gopher activity probably aids in the establishment of deep rooted perennials, such as dandelions, lupine, and sneezeweed, in the sod.

HOW BLUEGRASS GROWS

Bluegrass assumes three common growth forms under western conditions. Normally, it is of tufted habit with several flower stalks rising to about 20 inches; most of the leaves are densely basal and about one-half the height of the culms. In favorable sites, especially where bluegrass has been protected from grazing so that a heavy mulch blanket has accumulated, its habit is more that of the hay or meadow grasses. Growth consists of many culms rising 20 to 36 inches from the root-stocks without a pronounced basal tuft of leaves. Culms are somewhat more leafy than in the first form. A third form, assumed under heavy grazing, consists of a uniform sod of short basal leaves and scattered flower stalks rising to 3 to 15 inches.

These variable growth forms, particularly as influenced by grazing, may have induced early botanists to split the species into several varieties or additional species.

Measurements of bluegrass seedstalk heights in Colorado were as follows:

	Severely Grazed	Moderately Grazed	Protected
June 1	3.9 in.	5.6 in.	7.7 in.
October 28	14.9 in.	18.2 in.	20.7 in.

Weaver and Darland report that in a Nebraska pasture grazed moderately for several years, bluegrass foliage was 9 to 10 inches and flower stalks 12 inches. On a closely grazed area foliage grew to 1.5 to 2.5 inches and flower stalks 3 to 5 inches.

While bluegrass is commonly referred to as a turf grass or sod grass, under western conditions it may be most conveniently grouped with the shortgrasses. It either has or is capable of growing much of its leafage close to the ground. Thus, under grazing pressure, it differs from most bunchgrasses in that it retains a fair amount of photosynthetic surface, while the bunchgrass stubble consists largely of culms. It depends more upon vegetative means of spread than upon seed. Like short grasses, it is rather intolerant of shading, but is quick to spread when taller vegetation is weakened or killed.

Bluegrass has a unique seasonal pattern of growth which prevails throughout the bluegrass area. Low soil temperatures normally inhibit growth for some weeks after the first "greening up" occurs - usually in late April. After mid-May, growth is extremely rapid, and reaches a zenith about the first week in June. Completion of flowering and formation of seed occurs during the next three to four weeks, usually with little increase in volume. Beginning sometime in July and extending into the middle or latter part of August, there is little increment in volume. When soil temperatures again drop well below 80° F in late August or September, a period of regrowth normally occurs if moisture conditions are suitable. On much of the western range this fall growth is very uncertain because drought conditions often prevail.

In eastern Canada, Bird compared the relative development of four common pasture grasses, with the following results.

	Begin to Head	Seed Formed
Ky. Bluegrass	May 29	June 25
Smooth brome	June 5	July 6
Timothy	June 23	July 19
Redtop	June 23	July 19

The normal midsummer dormancy is a serious problem wherever continuous summer grazing is practiced. McConkey estimates that bluegrass herbage production drops at least 40% in July and August. Some investigators advocate the replacement of bluegrass with other grasses. Some suggest planting legumes, especially white and ladino clover with bluegrass to overcome this period of low production.

In a study near Estes Park, Colorado, it was found by Schwan, Hodges and Weaver that where bluegrass was grazed very short during the summer, volume production after June 1 was about 36% of the total annual growth. Under moderate grazing, growth after June 1 was 39%, and with total protection it was 45% of the total annual growth. However, during an extremely dry summer the severely grazed area produced only 9 percent of the total annual growth after June 1, whereas the moderately grazed and protected areas produced about 30% after June 1.

The reason for this improved summer production under moderate grazing and protection was assigned to the blanket of mulch which conserved soil moisture and reduced summer soil temperature. This indicates that the growth pattern may be appreciably modified by good range or pasture management.

Peterson states that grazing at full capacity in spring weakens the sod, decreases ground cover, and favors weedy annual species. He concludes that a good grass cover in midsummer is necessary to provide insulation and to discourage weeds.

Another characteristic of bluegrass growth is its tendency toward low yields. Most investigators regard it as a relatively undesirable pasture grass for this reason. Bird gives the following comparison which is typical of many others.

Dry yield in tons per acre:

	Yield 3-Year mean	After effects of close clipping 2-Year mean yield
Smooth brome	2.58 (141%)	1.26
Timothy	2.43 (132%)	1.21
Redtop	2.26 (124%)	1.07
Bluegrass	1.83 (100%)	.87

Clark cites yield figures for central Utah. The volume production of bluegrass was very low compared with crested wheatgrass, bluebunch, slender wheatgrass, smooth brome and mountain brome. The yield of bluegrass was similar to that of Indian ricegrass and letterman needlegrass. In Nebraska it is estimated that the replacement of native bluestems (Andropogon spp.) by bluegrass, as a result of severe grazing, will result in an overall reduction of forage yield of at least 35%.

Brown and Munsell differ with these investigators and conclude that quality and quantity of bluegrass forage is about equal to that of orchard grass, Rhode Island bent or timothy, and that the seasonal production is not appreciably different from the others. It is probable that these opposed viewpoints are the result of different treatments of the study areas.

Hughes, in Iowa, did not notice a decline in herbage production, as a result of close clipping, until the fourth year. Other investigators obtained much quicker responses. Observation, as well as one isolated study, indicates that bluegrass responds rapidly to changes in management on western ranges. In this respect it is different from the important bunchgrasses. There is general agreement among observers, that bunchgrass ranges decline rather slowly under excessive grazing. Recovery is equally slow, in some cases requiring 25 years or more before distinct improvement is noticeable. Wide differences in bluegrass and bunchgrass sites may account for this.

The study by Schwan, Hodges and Weaver, near Estes Park, indicates that bluegrass production doubled after one season of light grazing. Another phase of the same study (unpublished) indicates that deterioration is equally rapid. One spring and one fall clipping, at the ground line, of bluegrass ungrazed for 8 years, resulted in a decline of 36% in weight of herbage produced during the next growing season, compared with adjacent unclipped grass.

In this study, herbage production leveled out under heavy and moderate grazing and each maintained its plane for six years except as influenced by weather. Precipitation was considerably above average the first three years, much below average the fourth and sixth years, and about average the fifth year. While fluctuations, presumably caused by weather, were great, the moderately grazed range consistently produced about twice as much herbage as the heavily grazed range. (Fig. 2.)

The ungrazed plot improved very markedly the first three years. The decline in annual forage production was relatively greater under complete protection than under moderate or heavy grazing during the last three years. It is not known if this is a response to unfavorable weather, or if it is a result of non-grazing. Since bluegrass invasion often is a response to excessive grazing a certain amount of grazing probably helps maintain bluegrass sod.

In another nearby study (unpublished) near Jamestown, Colorado, where the site was drier, and more gravelly, adverse weather resulted in a very sharp loss in bluegrass density on heavily grazed range.

Bluegrass averages about 2-1/3 million seeds to the pound. Bluegrass is slow to become established. Plummer and Finley found in Utah that germination and emergence were good. However, 35 plots seeded at various times were rates as failures or very poor because of the very low survival of seedlings.

With reasonable freedom from competition, the stand is filled in by rhizome growth. During the first year the bluegrass plants become established and produce very few rhizomes. Studies in Missouri indicate that bluegrass has two periods of rhizome extension - spring and fall. Fall rhizome growth was practically as rapid as spring growth. Rhizome growth is especially rapid during favorable weather when the stand has previously been thinned by drought. Thus, bluegrass recovers quickly in the absence of competing vegetation. In Nebraska, where bluegrass as well as the native prairie grasses were very severely decimated by the Great Drought of 1934-36, profuse seeders, like the dropseeds, became established first. Also, the prairie bunchgrasses recovered quickly with the return of good growing conditions. The recovery of bluegrass was very slow over a period of several years. Bluegrass spread aggressively when the prairie plants were weakened by severe grazing.

Bluegrass forms few rhizomes in a dense sod. Root and rhizome growth in established swards practically ceases in summer. High soil temperatures are considered responsible. This is followed by the characteristic sharp reduction in top growth. At this time, bluegrass roots and rhizomes are usually reduced.

In Missouri, irrigation in summer caused the death of older rhizomes and had an exhaustive effect on the grass. The watering encouraged weed growth but the competition from bluegrass was reduced due to the exhausting effect. It was concluded that summer dormancy is a natural protective device. It was found that the loss in weight of roots and rhizomes during July and August was much less when bluegrass was harvested once or twice when fully developed.

(hay cut) than when cut to one inch every two weeks. Fall drought retarded root and rhizome growth and food storage. During the spring, when top growth was most rapid, close defoliation resulted in a greater loss of carbohydrates from the rhizomes. In these same studies it was noted that bluegrass root development was affected much less by repeated defoliation than was quackgrass, smooth brome, timothy or orchardgrass, and also less than tall prairie grasses. The retarded development or loss of rhizomes in summer was partly counteracted by larger gains in rhizomes in autumn, if soil moisture was adequate for good growth.

In Nebraska, Weaver found that bluegrass roots and rhizomes decayed more rapidly than those of prairie grasses. This is probably a factor in soil erosion, since undecayed roots may promote retention of soil aggregates and resist soil movement. At Manitou Experimental Forest in Colorado, bunchgrass, ungrazed for 7 years, had a mulch layer of 2993 pounds per acre. Near Estes Park, at the same altitude, bluegrass protected for 7 years had 2160 pounds of mulch per acre. It seems evident that fine-leaved bluegrass mulch disintegrates more rapidly than the native bunchgrasses, although mulch accumulation may vary during a given season and many more comparisons are needed to establish a prevailing ratio.

It has been found that harmful root interactions may occur when other grass species are present in a bluegrass stand. Under greenhouse conditions bluegrass produced from 50% to 80% more foliage per plant when grown alone than when grown with redtop or with Canada Bluegrass. The dry weight of roots was also greater in pure stands.

Bluegrass has a very shallow root system. Partridge found that bluegrass roots were distributed as follows: 75.5% in 0-6" layer; 12.1% at 6-12"; 7.0% at 12"-18"; 5.1% below 18". Other investigators confirm this general pattern.

Darrow reports that roots were thick, white and succulent when soil temperatures were 59° F. At 95° F they were small, brown, densely tufted and mature.

Under laboratory conditions bluegrass was least injured by soil drought and by low soil temperatures when compared with 14 other turf grasses commonly grown in the Northeastern bluegrass area. High soil temperatures were more destructive than high air temperatures.

Julander found that bluegrass was low in drought resistance compared to wheatgrasses, smooth brome and buffalograss. Grasses which had been protected or moderately grazed accumulated excess food reserves and were better able to resist heat than overgrazed or heavily clipped plants, which did not accumulate food reserves. Heavy grazing of bluegrass resulted in lessened drought resistance. He concludes that grazing management should provide for (a) hardened plants able to resist drought; (b) adequate food reserves for respiration and for vigorous recovery after drought; (c) reduction in drought conditions by a protective vegetative cover and mulch which guards against high soil temperatures and water loss.

Sprague and Graber found that the daily rate of water utilization by bluegrass increases directly with the rate of top growth accumulation and is highest during the period of flowering and seed setting. Water utilization remains low and constant when a vegetative stage of growth is maintained by clipping or grazing. However, the closely clipped grass required more water to make one unit of top growth. Repeated defoliation lowered food reserves severely. When growth is limited by reduction in the reserves of bluegrass or by nitrogen deficiencies, the water requirement is increased.

The authors suggest that close spring grazing of bluegrass would maintain the greatest soil moisture reserve during drought for subsequent growth. One must conclude, however, that since resumption of growth requires increased amounts of water, it is doubtful if close grazing is good practice. The authors point out the results are offered to explain observed field responses, rather than to be recommended as desirable practices. The study employed the use of sealed phytometers and was limited to water use by the grass and transpiration loss. It did not take into account evaporation from the soil.

Robert J. Weaver's Nebraska field study agrees closely with the foregoing conclusions. He found that bluegrass in grazed pasture lost 88% as much water as bluegrass in prairie. However, the former produced only 73% as much top growth, so that 21% more water was used to produce a pound of herbage in the pasture compared with the prairie type. Much of the greater water loss in pasture was assigned to increased evaporation from the exposed soil surface resulting from the more open grazed bluegrass sod.

The tendency for vigorously growing bluegrass to rapidly deplete soil moisture reserves in the zone of root growth is illustrated in Brown's studies in Missouri. Soil moisture content was about the same under bluegrass as under adjacent bare ground in early June at 0-6" depth. The moisture under bluegrass dropped to about 1/2 by July 1 and to 1/3 or less by July 15, compared with the moisture content of the bare soil.

In the same studies it was found that monthly averages of mean soil temperatures at 1/2" depth were 5° - 7° F higher from June 1 through August under closely mowed bluegrass than under unmowed grass. The diurnal temperature range was reduced under mowed grass compared with bare ground.

In Colorado, mulch was applied to very closely grazed bluegrass by Schwan, Hodges and Weaver. During a year when only 5-1/3 inch of precipitation fell during the growing season, total annual yield was increased 42 percent and 50 percent, respectively, under medium and heavy mulch. Thus, a mulch layer such as results from light or moderate grazing, is an important ameliorating factor during times of drought.

In Kansas, a study was made on the effects of periodic burning. Burning was done once a year when soil was moist. Bluegrass increased on all unburned plots and was either diminished or eliminated in all burned plots. Burning favored the bluestems (Andropogon spp.) over a period of six years.

BLUEGRASS IN THE PLANT COMMUNITY

Bates indicates that in England bluegrass is characteristic along paths, subject to repeated trampling, but where the soil is stable and does not shift. It persists under trampling and, presumably, on compacted soils.

Anderson compared prairie areas in Iowa which had been continuously grazed for a long time, except that one had been protected against grazing about five years. Bluegrass, which was established when the protected tract was grazed, grew vigorously when grazing ceased, crowded out weeds and resisted invasion by taller native plants. On drier areas, prairie species like *Andropogons* were invading. Other native species began to occupy very moist areas. Bluegrass remained dominant in intermediate moist, well drained areas.

In Wisconsin, Fuelleman and Graber found that improving the bluegrass cover in deteriorated pastures by seeding legumes, by improving management, and adding fertilizer, the number of ragweeds were reduced from 423,000 to 60,000 per acre or 85.7 percent. Horseweeds were reduced 92.1 percent.

Pickford, in studies of mountain meadows in Oregon, indicates that when bluegrass displaces tufted hairgrass (*Deschampsia caespitosa*) a downward trend is indicated. Also, when the range conditions had deteriorated from "excellent" or "good" to "fair" condition, bluegrass was the characteristic grass species and exceeded tufted hairgrass in density.

In Iowa, Peterson found that close grazing from mid-May to early July, and again during September and early October, resulted in progressively more weed grasses as the experiment progressed. Crabgrass (*Digitaria sanguinalis*) and "povertygrass" (*Aristida oligantha*) were the principal invaders. He attributes this invasion to the weakened sod, the result of grazing to full capacity each spring.

According to studies reported by Diller, the woodland pastures of the Corn Belt, which comprise about one-third of all the pasture land east of the prairies, mostly "have been so seriously injured by continuous overgrazing as to be inadequate for the satisfactory maintenance of livestock and ruined for sustained timber production." Diller shows first, a sharp thinning out of the characteristic forb forest floor cover, followed by increased grazing on, and destruction of, woody plants, including tree reproduction. As the weed cover is reduced and the canopy opened, Kentucky bluegrass increases in density. In the oak-hickory types of northern Indiana, no bluegrass was recorded in 43 ungrazed quadrats; bluegrass was recorded in 38% of 44 quadrats in woodland in the transition stage to open parkland; it occurred in 82% of 45 quadrats where continued overgrazing had resulted in open park types. Bluegrass density increased from 0% to 6.3% to 17.2% for the three woodland pasture stages, respectively. Similar results were recorded for the beech-maple type.

In Nebraska, bluegrass takes over prairie sites, especially on flats and in swales, when the native prairie grasses become weakened from excessive grazing. If severe grazing continues for a few years, the bluegrass sod

becomes weakened and less dense and native weedy forbs and shrubs spread rapidly. Weeds usually found only in old pastures become established and foreshadow the final weed stage in degeneration. Buckbrush (Symphoricarpos) is one of the invaders in degenerated bluegrass. Ironweed (Vernonia sp.) and thistle (Cirsium) are other invaders. Following the Great Drought, bluegrass still comprised 56% of the cover in 1937, but was so weakened that only 3% of the stand remained in 1938. Bluegrass had not recovered much in these Nebraska areas by 1940. Sand dropseed (Sporobolus cryptandrus), sideoats grama (Bouteloua curtipendula), peppergrass (Lepidium) and Pursh's plaintain (Plantago purshi) increased rapidly during early stages of recovery. Big and little bluestems, and blue grama (Bouteloua gracilis) increased steadily and consistently during 1938, 1939 and 1940.

Its place in the succession - Most typically, bluegrass is an invader which rapidly takes over if there is a parent stock, when the cover is depleted or open and when temperature, moisture and soil conditions are reasonably favorable. It suffers sharp setbacks during drought but resumes the invasion process whenever climatic conditions again become favorable.

As has been pointed out, bluegrass reacts like a short grass. Like the native short grasses, it represents a successional stage below the bunch and mixed-grass stages. When the climax or sub-climax bunch grasses are weakened by heavy grazing, a lower stage may intervene in which profuse seeders, like dropseed or needlegrass, may become dominant. However, if bluegrass is present in the type, it begins its march, chiefly through very rapid rhizome extension. With continued heavy grazing, bluegrass becomes the dominant plant. Under moderate to fairly heavy grazing it maintains its stand very well and persists for many years. Under continuous close cropping, however, deep-rooted weeds, like thistle or dandelion, become established and are able to tap the moisture supply below the zone of bluegrass roots. Continued heavy grazing seems to inhibit rhizome formation, probably through decreased carbohydrate storage, through induced drought, and deterioration of soil quality. Then bluegrass is reduced in area to separate islands of sod, first on ridges and slopes. Observation indicates that reduced infiltration capacity and slight replenishment of soil moisture reserves is partly responsible. The tendency for bluegrass to deplete soil moisture during the early growing season is probably an important factor. Sharply increased surface soil temperatures, because of lack of mulch, undoubtedly add to the impact of climate. The stand becomes a reduced and declining aggregation of sods, with such plants as Tumblegrass (Schedonardus sp.), mat muhly (Muhlenbergia squarrosa), sleepygrass (Stipa robusta), fringed sagebrush (Artemisia frigida), dandelion (Taraxacum officinale), silver cinquefoil (Potentilla anserina) and others taking over the site. Under certain conditions, shrubs, like bush cinquefoil (Potentilla fruticosa), big and silver sagebrush (Artemisia tridentata and A. cana) or rabbitbrush (Chrysothamnus) with an admixture of perennial and annual weeds, may take over. These are common invading species in the central Rockies.

If grazing pressure is released, the locality and prevailing vegetation determine the stages. Normally, bluegrass reasserts dominance. Usually it crowds out its competitors and in three to four years may form a solid bluegrass sod. It produces a fairly heavy mulch and increases its vigor

and height. If the local climax consists of bunch grasses, and if a source of seed or parent plants are present, these plants are able to penetrate below the bluegrass root zone and reestablish themselves. This process is especially pronounced following a drought when the bluegrass sod is reduced. The bunch grasses and palatable deep-rooted forbs are able to become established and tap deep moisture before the bluegrass can close ranks.

On the Eastern Slope of the Central Rockies, needleandthread (Stipa commata) and other secondary grasses often replace bluegrass following a long period of protection, as an intermediate stage between bluegrass and the climax.

During the course of bluegrass retrogression and also following drought, cheatgrass (Bromus tectorum) may become established and form a highly persistent annual stage. There is observational evidence that if bluegrass is not continually closely cropped it is able to extend its sod and eventually drive out the annual grasses on bluegrass sites.

Dutch white clover and some of the native clovers are frequently associated with bluegrass on the better, moister sites. The clovers do not persist in any quantity when bluegrass is tall and rank. If bluegrass height is reduced by moderate to heavy grazing in spring, the clovers tend to increase. Therefore, an abundance of clover, if very short and matted, and especially if mixed with dandelion, thistle, cinquefoils, may be an indicator of overgrazing, type deterioration, and downward succession.

In the Missouri studies referred to earlier, Whitt suggests that the calcium increase under bluegrass sod encourages the invasion by lime-loving white clover. The clover steps up the rate of nitrogen fixation and the subsequent increased bluegrass growth crowds out the clover, thus accounting for the cyclic increase and decline of white clover.

Originally, many bluegrass sites were meadows with peaty, saturated soil. Most commonly, these sites were dominated by sedges (Carex), Canada reedgrass (Calamagrostis canadensis), tufted hairgrass (Deschampsia caespitosa), redtops (Agrostis), willows (Salix), alder (Alnus), water birch (Betula fontinalis), and similar moisture loving plants. Where gullying has taken place, the original soil, moisture and plant combination often can be regained naturally through beaver activity. This brings about a period of flooding and the gradual redevelopment of meadow or swamp soil conditions.

On drier sites in the Rocky Mountains, especially in the Ponderosa Pine zone on favorable sites, bluegrass has replaced the sub-climax bunch grasses, Arizona fescue, blue-bunch wheatgrass, and spike fescue. When grazing pressure is relieved, invasion by quaking aspen frequently takes place. This is an intermediate stage leading to the fir, spruce or pine coniferous climax, since aspen aggressively invades by means of root sprouts.

In the Black Hills and in the central and northern Rocky Mountains, many bottoms and small valleys originally were dominated by forbs and shrubs. Heavy grazing has converted many of these types to Kentucky bluegrass. If the severity of grazing is sufficiently decreased, the original shrubby or weedy cover will be gradually reestablished. Such a cover will be considerably less valuable for grazing, particularly for cattle. In Ohio and

Indiana, it has been found that woodland pasture was 22% less nutritious than converted open pasture and produced only one-fifth as much green weight of forage. However, there will be a certain definite improvement in watershed, wildlife, and recreation values which have not been studied in sufficient detail to permit accurate and comprehensive conclusions. There are many valleys in the West where bluegrass persists but where excessive grazing has destroyed willows, aspen, and other shrubby vegetation. This change in cover has increased the hazard of channel cutting, soil moisture reduction, and eventual bottom land destruction.

The tendency for bluegrass pastures to become weedy when lightly grazed is often an indication of successional trends toward deep-rooted species and higher canopies in the direction of the hardwood forest. There is an indication in Diller's studies that conditions in overgrazed woodland hasten the decomposition of leaf litter with a resulting increase in nitrogen content of the soil. This may suggest why nitrogen-loving bluegrass invades overgrazed woodland so promptly and rapidly.

BLUEGRASS AND WATERSHEDS

Extensive tests present impressive evidence that infiltration rates of grassland are reduced by livestock grazing. At the Manitou Experimental Forest, in Colorado, on ponderosa pine-bunchgrass ranges, it was found that both heavy and moderate rates of stocking increased surface runoff markedly over prevailing runoff in ungrazed areas. Soil loss was sharply accelerated under heavy grazing. In Nebraska, in writing of prairie vegetation, Weaver and Hansen say, "...It would seem that two years' growth of grasses without trampling in the protected pasture and the winter's freezing and thawing had increased the rate of water infiltration." Numerous studies in the East, as well as the West, indicate that these conclusions apply also to bluegrass.

The Rocky Mountain Forest and Range Experiment Station made infiltrometer tests west of Delta, Colorado, where the dominant grass in the cover was bluegrass. Five paired random samples compared infiltration rates on an area protected from grazing with an adjacent area heavily grazed by cattle. Following is the average infiltration rate during the last 20 minutes of the series of 50 minute runs.

Protected 8 years	3.89 inches per hour
Utilized 80% by cattle.....	.34 inches per hour

Eight years protection from grazing had increased the infiltration rate eleven times.

A series of tests made with simple ring infiltrometers in Colorado, Wyoming, and South Dakota suggest that the infiltration rate of soil under bluegrass varies, at least roughly, with the severity of grazing. Although precise figures are not available at present, there is considerable observational evidence which indicates that infiltration rate also varies with the prevailing quality of bluegrass ranges.

The Rocky Mountain Forest and Range Experiment Station reports the following results from a series of tests on the Gunnison National Forest. (Artificial rainfall applied at 5 in/hr for 50 minutes).

TYPE	Herb. production (lbs/A. airdry)		Percent. cover		Infilt. in./hr	Runoff %	Eros. lb/A.	Slope %
	Grass	Weeds	Herbge	Litter				
Good bunchgrass	1478	340	24	56	4.8	3	10	15
Poor bunchgrass	1298	931	33	47	4.2	9	479	18
Brome-weed	776	789	31	48	4.2	13	156	12
<u>Bluegrass</u>	<u>599</u>	<u>504</u>	<u>30</u>	<u>47</u>	<u>2.3</u>	<u>48</u>	<u>251</u>	<u>10</u>
<u>Needlegrass</u>	<u>414</u>	<u>303</u>	<u>21</u>	<u>34</u>	<u>3.6</u>	<u>24</u>	<u>552</u>	<u>16</u>
Lush weed	388	1185	34	28	4.5	8	102	13
Poor weed	150	920	16	12	2.5	42	5737	15

This table indicates that bluegrass had the lowest infiltration rate and highest percentage runoff, although it occurred on the most moderate slope, compared with six other types. Rate of erosion from the bluegrass area was low. However, the erosive effects of high runoff over long slopes and on other vegetation types below the bluegrass, were not measured, but could be expected to be great. The report observes: "Relatively high runoff from bluegrass and needlegrass may result in gully formation and stream bank cutting."

Bluegrass mulch (litter) has a high density in terms of ground surface covered, even under conditions of relatively low volume production. The preceding table indicates that this high-density mulch was ineffective in preventing surface runoff. This lends strong support to a common observation that even on closely grazed bluegrass range the ground between plants is usually well covered with a layer of dead leaves, but under such conditions the layer is very thin, and low in volume and substance. Percentage ground covered by bluegrass mulch should not be compared with the percentage mulch in bunchgrass stands unless the volume or depth of mulch is also compared.

In one isolated series of tests on the Arapaho National Forest where patches of bluegrass were mixed with native grasses in a long-protected fenced area, it was found that danthonia (*Danthonia parryi*) had an infiltration rate about six times greater than bluegrass. Slender wheatgrass stands in the same area had infiltration rates greater than bluegrass, although somewhat lower than danthonia. Additional studies are needed before definite conclusions can be drawn, but this one test suggests that bluegrass in itself, without the influence of grazing, may be less efficient in maintaining high infiltration rates than native climax grasses.

Kennedy and Russell found that the specific gravity of surface soil under Kentucky bluegrass was markedly lower on areas clipped once a year or unclipped for seven years, compared with more frequent clipping. They observe that differences in specific gravity (indicative of soil density or compaction) due to clipping frequency probably are less than would result from grazing because of the absence of trampling.

Johnston-Wallace, Andrews and Lamb found that heavily grazed and fertilized bluegrass lost very little soil or water, compared with bare soil, and rates of erosion and runoff were negligible, both for heavily grazed and lightly grazed sod. The factors which influenced these results cannot readily be correlated with many other studies which are at variance with these conclusions. Several other eastern studies on bluegrass arrive at conclusions similar to the Delta bluegrass study, and indicate that under increasingly heavy grazing, surface runoff increases before severe erosion becomes apparent.

Musgrave and Free show that close vegetation such as bluegrass controls runoff very appreciably, compared with land in corn or fallow land. This may be accounted for by sustained high infiltration rates and by the effect of the grass in decreasing runoff velocity. The effect of lower velocity becomes particularly important when studied on areas of considerable size.

Free found in Iowa that 8.6% of total precipitation was lost as runoff for corn, compared with 1.4% for bluegrass sod. He also reports that the sum of transpiration, evaporation and percolation losses from a three foot profile were 94.2% of total precipitation from corn and 103.2% from bluegrass. The loss above 100% from bluegrass "means that the net decrease in soil moisture for the period has been greater than the total loss of moisture from runoff." Free's studies do not cover the point, so vital to any consideration of watershed values, of how much of this loss may be assigned to percolation, and addition to ground water reserves. He warns that the term "moisture conservation" must be used very carefully in order to prevent misunderstanding.

Duley and Domingo studied infiltration on bluegrass plots with "rainmaker" apparatus in eastern Nebraska. Their report indicates an intake in inches during a $1\frac{1}{2}$ hour test as follows:

Bluestem (<u>Andropogon furcatus</u>) meadow, dense.....	4.17 inches
Bluegrass under trees, some litter.....	2.53 "
Bluegrass, very little litter, trampled.....	.88 "
Forest, no grass, some shrubs, 1 to 2 inches leaf litter.....	14.13 "

It may be assumed from the above that where hardwood or shrubby bottoms have been converted to heavily grazed bluegrass, the infiltration rate has been very drastically reduced. In this study the forest type with leaf litter, absorbed 15 times as much water during the $1\frac{1}{2}$ hour test as did overgrazed bluegrass. Bluegrass sod in relatively good condition absorbed less than one-fifth as much water as the forest soil.

These authors cite work by Henrici in South Africa that transpiration water loss may be as great from grass as from forest. If this applies to compacted bluegrass sod which has been converted from former forest, it may be assumed that the loss in total watershed values is very great, since soil conditions usually are deteriorated, without any compensating saving in soil moisture.

They also state that: "The idea that water tends to follow roots into the soil at a much faster rate than if the roots were not present, does not seem to be borne out by the results of these tests. ...The high intake of water on grassland must be attributed largely to the effect of the top growth which protects the sod from the dispersing effect of raindrops."

While the foregoing remark refers to studies on native grass meadow, earlier studies in Nebraska suggest that this is probably true for most grassland types, including bluegrass. The authors state that: "Where grass is not overgrazed and growth is dense, the infiltration rate is likely to remain high for a long time and continue at a high point during successive rains." This comment may have an important bearing on Free's observation on the value of bluegrass in water conservation.

Diller points out that in northern Indiana, the transition from hardwood forest to open woodland-bluegrass, under continuous heavy grazing, is from moist to dry conditions. Reduced crown canopy increases wind movement and allows the ground to dry out more rapidly. During dry periods the soil moisture content in the A, B, and C horizons of the open park woodland is lower than in ungrazed woodland or where overgrazing has resulted in only partial conversion to the open park type.

Bullard has summarized a large number of studies dealing with the influence of forests on watershed phenomena. Many of these studies compare the relative influences of forested and open areas. Since heavy grazing often reduces or eliminates broadleaf trees or shrubs and converts these areas to open bluegrass, the effect must be considered detrimental to watersheds, as indicated by the following general conclusions:

- (a) The rate of runoff is frequently greater in open areas than in forest;
- (b) While total snow accumulation may be greatest in openings, the rate of snow melt is more rapid than in forest;
- (c) Ice layers frequently form at the bottom of the snow pack in the open areas and impede infiltration;
- (d) Soil freezing and frost penetration are greater in open areas than under tree canopies and adversely influence infiltration, spring runoff, and the recharge of soil moisture;
- (e) Soil freezing draws soil moisture upward and dries out the sub-soil.

Brown's studies in Missouri indicate that bluegrass depletes the soil moisture in the upper soil horizons. Although soil moisture percentages were approximately the same under bare soil and under adjacent bluegrass in early June at the 0-6" depth, this value dropped to 1/2 by July 1 and to 1/3 or less by July 15 under bluegrass. In other words, soil moisture was depleted about three times more rapidly under bluegrass than under bare soil during this 1½ month period. This agrees with Weaver's findings that vigorous prairie vegetation depleted soil moisture more rapidly than more open vegetation. This indicates that bluegrass, like other grasses, creates a soil moisture deficit during the growing season.

Observational as well as detailed research evidence in Colorado and other western states, is that on closely grazed bluegrass sod, runoff is great, but soil erosion within the sod is light. Close cropped bluegrass sod is very seldom pedestalled and surface soil layers and light

mulch are usually intact. This is not true where the sod is broken up into separate islands. Near Estes Park, there is little sign of erosion in continuous short bluegrass sod, but definite erosion gullies have developed where sod has disintegrated and where more open vegetation has replaced bluegrass. Most frequently active cutting in bluegrass begins in cattle trails and drainage-ways. The increased runoff from closely grazed bluegrass causes severe gullying in drainage-ways, while the sod area remains essentially intact. Because of the shallow root system of bluegrass, cutting often proceeds rapidly into the sub-stratum and the effect of the dense sod is lost.

Under western conditions it may be concluded that both lightly and heavily grazed bluegrass is efficient in preventing soil erosion if the sod is continuous and unbroken. Continued erosion prevention is precarious under heavy use because of the danger of gully cutting on bared areas. High runoff results during high intensity rainfall on close cropped sod and hastens gully cutting, wherever the sod is discontinuous.

The maximum efficiency of the three principal functions of a watershed cover -- prevention of soil erosion and siltation, reduction of flood crests, and maximum delivery of usable water -- can best be obtained by vegetation which will promote the highest infiltration rates for sustained periods of time. In the case of bluegrass, as well as other vegetation, this means that the surface soil must be uncompacted, must have high humus content, and must be protected against raindrop splash. In addition, it should have vegetation of adequate height and density to reduce and slow down overland flow from rapidly melting snow and high intensity rains. The effect of grazing on trees and shrubs must be considered when these vegetation forms are present on bluegrass ranges.

The studies referred to in this section, as well as many others, indicate that on grassy watersheds the efficiency of the cover is quite closely proportional to the density and volume of the live and dead vegetation. This, in turn, is influenced by the intensity and time of grazing. However, the evidence indicates that bluegrass is less efficient in controlling runoff than are other perennial grass, shrub, and forest types under comparable conditions.

THE NUTRITIVE VALUE OF BLUEGRASS

It should be noted that percentage crude protein - or other nutritive elements - in itself does not give the relative yield of protein per acre, unless percentage is correlated with total forage yield. Thus, grazing bluegrass early in May, when percentage of protein is highest, may give a low yield of protein per acre because of the relatively short herbage.

Bird, in eastern Canada found that bluegrass in the short grass stage had 15.3% protein. When seed was formed, this dropped to 7.44%. Crude protein (average) of bluegrass (10.6%) compared favorably with timothy (9.01%) and redtop (9.40%) at the same growth stage. The bluegrass protein percentage held up better than for the other grasses. He reports the following yields of protein in pounds per acre, which reflect percentage of protein

and relative forage yield for each species.

Bluegrass	326 pounds	(100%)
Timothy	362 "	(111%)
Redtop	410 "	(126%)
Brome grass	494 "	(152%)

In Kentucky, it was found that protein was high (12% to 20%) in March and April, dropped to a low of 9% in July and rose again to 10-20% in August. Crude fiber attained a high of 25-35% in July. Brown found in Missouri that protein declined from 26.4% April 1 to 15.0% May 15, fluctuated about this level to August 15, rose to 22.6% in late August, and remained about this level through October. Crude fiber varied from 15.9% April 1 to 26.2% August 15.

In studies in Utah, bluegrass was highest in crude protein among seven range grasses. It was about average in fat and fiber, and was lowest in N-Free extract (carbohydrates) in June. Practically all shrubs and forbs were higher in protein than bluegrass. In September, bluegrass was lowest in fiber and next to highest in N-Free extract. In these studies relative volume production was not correlated with protein percentages.

Following are comparative analyses for bluegrass from the Black Hills in South Dakota.

	<u>Oct. 1</u>	<u>January 1</u>	<u>April 1</u>	<u>July 1</u>
Protein %	7.07	5.35	4.88	12.63
Fiber %	33.04	35.39	30.38	31.34
Moisture %	57.00	87.00	38.00	68.00
N-Free extract %	47.29	43.84	44.62	39.79
Calcium	.53	.52	.47	.33
Phosphorus	.21	.16	.09	.30

The addition of Dutch White Clover to the bluegrass sod markedly increases the nutritive value of the forage. White clover is reported by Archibald, Bennett and Ritchie as being about 50% higher in nitrogen than bluegrass, and correspondingly lower in crude fiber.

In interpreting these values it may be considered that good roughage containing 7-8% protein is satisfactory as a maintenance ration for mature animals. For rapid growth and gains in young animals, 10-12% is required. The minimum phosphorus content for growth varies from .10% to .26%. Young animals may require .37% phosphorus and .43% calcium. Mature animals are considered to require .17% phosphorus and .11% calcium.

In the West some ranchers maintain that the benefits of high protein content during the very early growth stages of bluegrass may be completely offset because the succulent, washy forage has a tendency to cause severe scours.

BLUEGRASS YIELDS

Comparative Yields When Grazed: Darland and Weaver report that on lowland prairies in eastern Nebraska, western wheatgrass and bluegrass had invaded a test pasture following drought and heavy grazing. It was, therefore, possible to compare yields and use where cattle, under very heavy stocking rates (6 yearling months per acre) had equal access to the three types.

	Yield		Consumption		% Use		Stubble Ht.
	<u>'43</u>	<u>'44</u>	<u>'43</u>	<u>'44</u>	<u>'43</u>	<u>'44</u>	<u>fall</u>
Western Wheatgrass	2.30	3.56	1.33	1.40	58%	39%	12" - 20"
Prairie Grasses	3.54	2.62	2.86	2.26	81%	86%	$\frac{1}{2}$ " - 3"
Bluegrass	1.78	1.88	1.68	1.65	94%	88%	$\frac{1}{2}$ " - 1 $\frac{1}{2}$ "

This indicates that bluegrass yields are much lower than the yields of native prairie grasses on the same site. With severe rates of stocking, bluegrass rapidly invades as the native grass stand deteriorates. As native grasses decline in vigor, more grazing pressure is diverted to the lower yielding bluegrass. Then the yields of the weakened bluegrass decline, leading to the disintegration of the sod, invasion by worthless forbs and shrubs, and destruction of all grazing values.

On a heavily grazed range near Estes Park, Colorado (72% average annual utilization) average annual production was 594 pounds per acre. On a part of this range, protected one year, and then grazed moderately (57% avg.) for four years, average annual production increased to 1192 pounds. Complete protection resulted in an average annual yield of 1565 pounds (Fig. I). Most interesting is the continuing increase in safe grazing capacity from year to year on the moderately grazed area of about 3 acres, of which about 2 $\frac{1}{2}$ acres are in bluegrass.

- 1943 - No control. Estimated safe capacity 1/4 cow-months
- 1944 - Total protection to allow recovery
- 1945 - 3/4 cow-months, util. = 62%
- 1946 - 3/4 cow-months, util. = 54%
- 1947 - 1 cow-month, util. = 47%
- 1948 - 1 cow-month, plus undetermined amount of trespass, util. = 65%
- 1949 - 1 cow-month, plus est. 12 days' elk use, util. = 38%
- 1950 - 1 $\frac{1}{4}$ cow-month, plus some elk use = 54%

Bluegrass density increased under moderate grazing from 24% to 40% during the 7 years.

Bunchgrass harvest studies were made at Manitou Experimental Forest, 100 miles to the south, but in the same zone, cover type, precipitation pattern and altitude as the bluegrass plots near Estes Park. However, soil and site quality are believed to be better at the Estes Park plots. The Manitou clippings were made at the end of 7 years' treatment. The Estes Park results are the averages for 5 years' treatment during the same period. These two studies afford an opportunity to compare bunch grass and bluegrass yields in

Fig. 1

Cumulative Volume Production of Bluegrass

Generalized curves derived from averages (Colo.) showing influence of three treatments on seasonal volume accumulation.

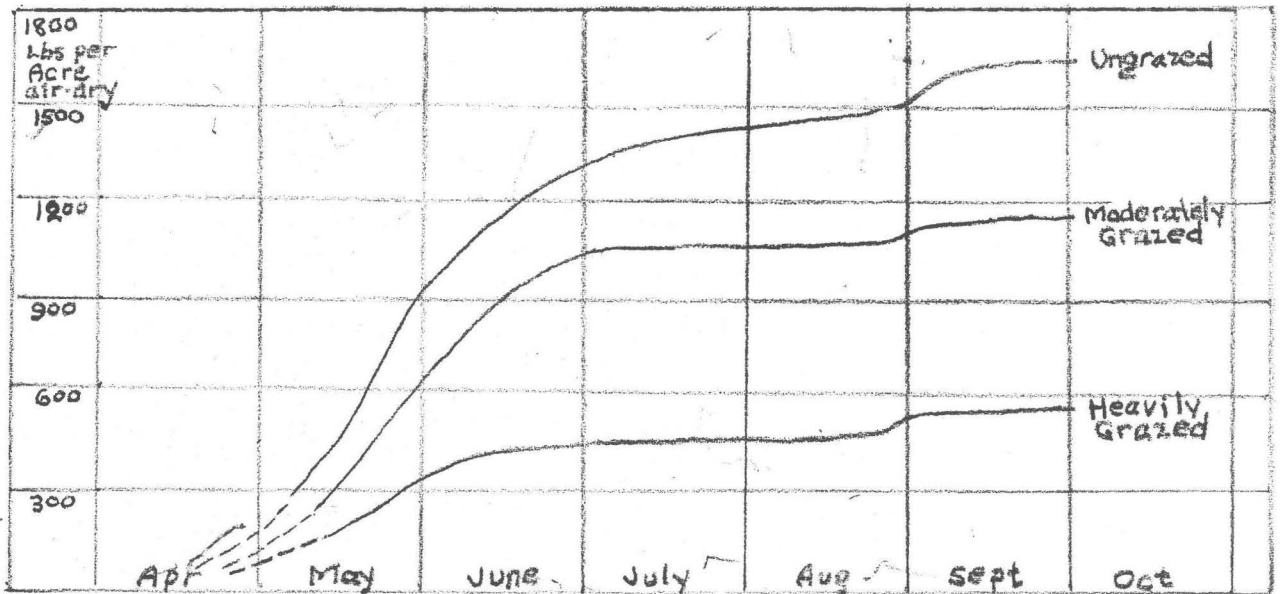


Fig. 2

Relative Volume Production in Response to Heavy and Moderate Grazing and Complete Protection. Correlated with spring and warm season precipitation. (Schwan, Hodges, Weaver).

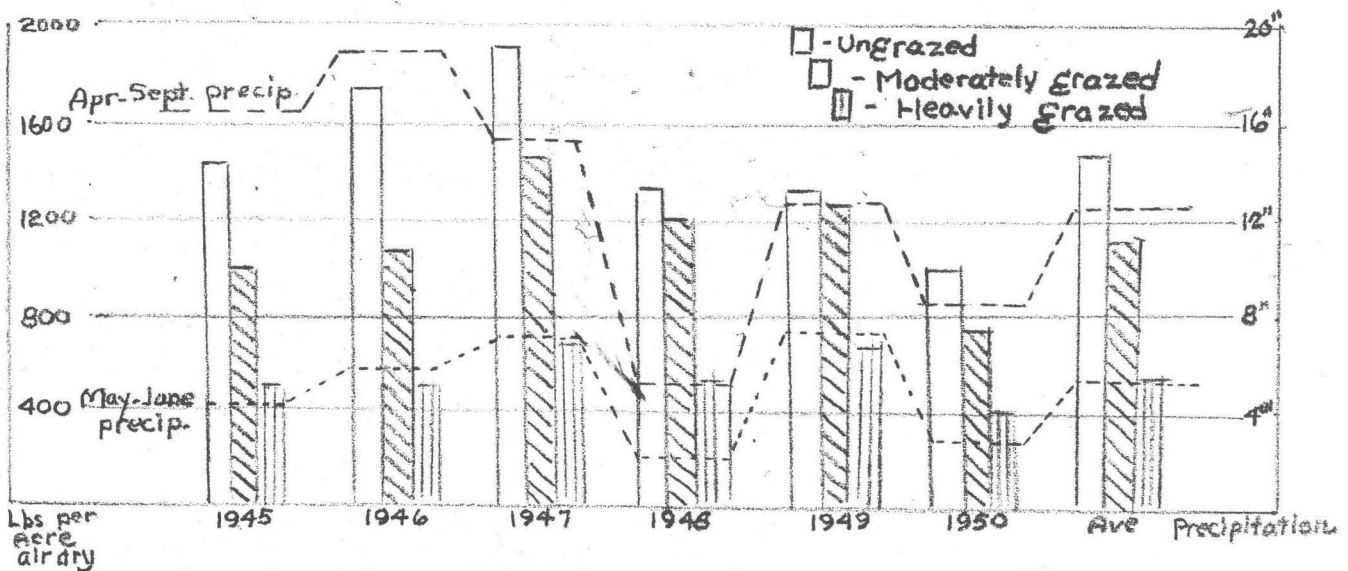


Fig. 3.

Normal Precipitation Patterns at Six Selected Stations. Nos. 1, 2, 3, representative of important bluegrass regions. Nos. 4, 5, marginal for bluegrass. No. 6 unsuitable for bluegrass unless supplemental moisture is available. May-June precipitation cross-hatched for comparison.

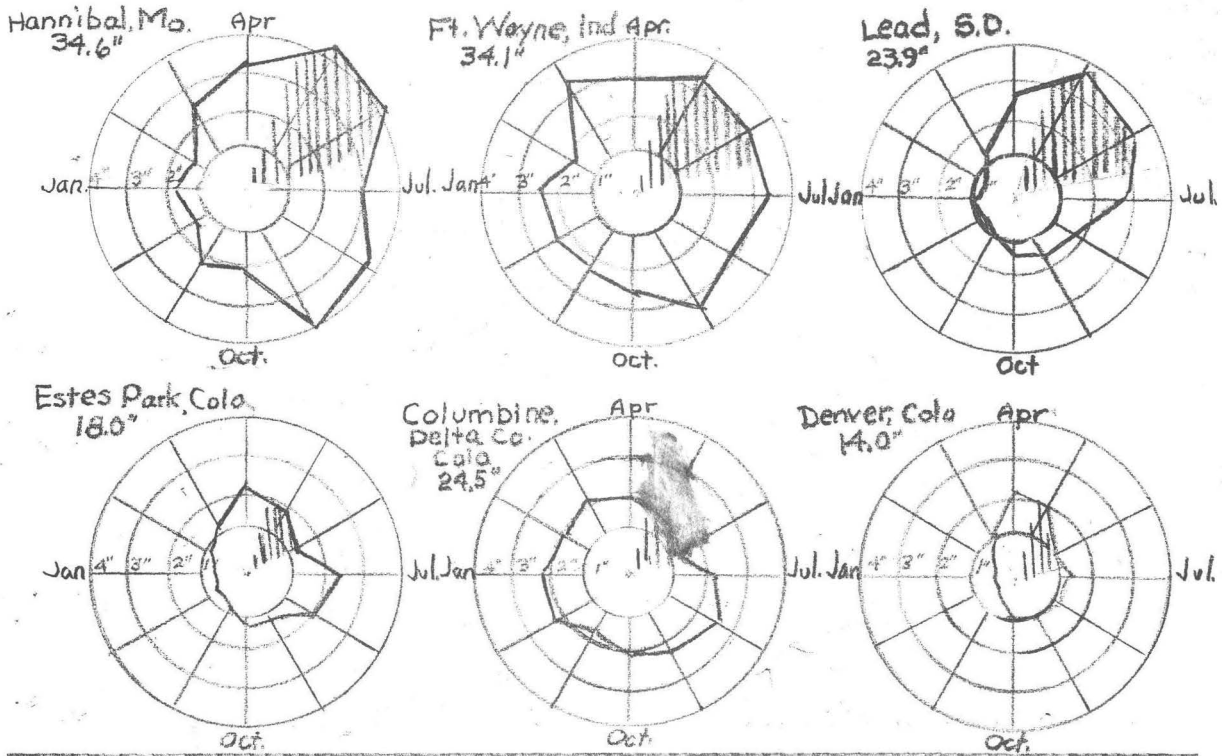
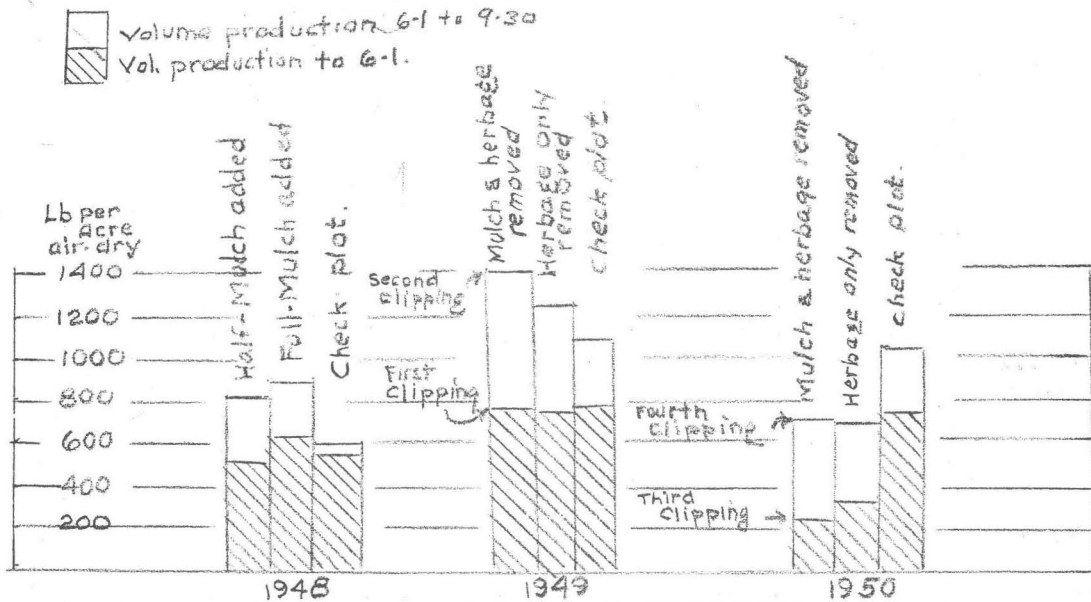


Fig. 4.

Response of Bluegrass to the Application of Mulch on Heavily Grazed Range and to the Removal of Green Herbage and Mulch on Ungrazed Range. Clipping apparently stimulated growth the first year but was detrimental to spring growth of the second year (Colo.).



the Colorado ponderosa pine type.

	Yield in lbs. per Acre, airdry.		
	Manitou		Estes Park
	Bunchgrass		Ky. Bluegrass
	All Herbage	Grass only	Grass only
Ungrazed	1980	1493	1565
Lightly Grazed	1115	841	----
Moderately Grazed	1174	784	1192
Heavily Grazed	938	476	594

Although grass yields only were computed at Estes Park, there was very little herbage other than bluegrass in the ungrazed and moderately grazed plots. The heavily grazed area is more weedy and the total yield of all herbage would be somewhat greater than the 594 pounds shown. In these areas spring precipitation averages more than two inches per month.

On the Western Slope of Colorado, spring precipitation normally is low and conditions are not ideal for good bluegrass growth. The Rocky Mountain Forest and Range Experiment Station in 1950 reported on bluegrass-bunchgrass yield comparisons near Gunnison. Bluegrass produced an average of 1000 pounds airdry herbage per acre compared with 2000 pounds for good bunchgrass (Festuca thurberi) in the same locality.

Height of Clipping - Harrison and Hodgson grew 6 species of plants in the greenhouse in sand and nutrient solutions. Bluegrass was clipped at different heights at weekly intervals for 7 weeks beginning when the grass was in the early bloom stage. Total yield for the seven clippings in grams, dry weight, was:

	Weight of Clippings	Total Weight of Plant*
Clipped at $\frac{1}{2}$ inch - - - - -	4.29	20.89
Clipped at 2 inches - - - - -	6.84	34.64
Clipped at 3 inches - - - - -	6.85	36.25
Check plants, unclipped - - - -	----	51.90

*Initial weight, plus yield, plus remaining weight one week after last clipping.

The authors observe: "Bluegrass withstood close cutting better than the other grasses because ---- it produced the most green leaves below a height of one inch. -- it produced more photosynthetic tissue close to the sand than did any of the other grasses."

All grasses were injured by close clipping. They rated in the following order, beginning with the one least injured.

Kentucky bluegrass
 quackgrass
 smooth brome
 timothy
 orchardgrass

The yields of underground parts, roots and rhizomes, decreased with severity of cutting treatment. The shorter a given grass was cut, the less top growth it produced.

Hughes conducted studies in Iowa on different harvest treatments of bluegrass. During the first three years of the study frequent close cutting resulted in markedly larger total yields. In the fourth year the differences in favor of close cutting were sharply reduced. This suggests that continued close cutting ultimately starved the roots to such an extent that yields were materially decreased. Yields were much larger when harvests were made every 40 days than when made every 10 days. This suggests that under Iowa conditions a larger harvest would be obtained with rotational grazing than with continuous grazing. Hughes found that delaying the first harvest in spring resulted in greater vigor but did not offset low fall harvest. Continued close harvesting resulted in a significantly smaller root system than when more cover was allowed to remain. The effect on rhizomes was even more striking. Close cutting gave larger yields of herbage, but spring growth was noticeably weaker and plots became increasingly weedy.

Kennedy and Russell compared yields from bluegrass clipped to 1/2 inch at 1, 4 and 8 week intervals; clipped to 1 inch at 12 weeks; once a year at 1 inch; and uncut for 7 years, and then harvested. They concluded that the yield was highest when cut to 1/2 inch at 8 week intervals. However, the yield of roots increased progressively from 4180 pounds per acre for clipping each week to 6960 pounds when it was not cut for 7 years.

McConkey in Ontario experimented with different cutting heights to determine effect on yield of unfertilized pasture -

Cutting Height	Dry Matter Per Acre
3 inches	1383 lbs.
6 inches	1700 lbs.
9 inches	2400 lbs.

Frequency of Harvest - McConkey also clipped bluegrass at different time intervals with the following results, without fertilizer treatment.

	<u>Dry Matter Per Acre - lb.</u>	<u>Crude Protein Yield Per Acre - lb.</u>
Cut weekly	1593	411
Cut every 2 weeks	1697	406
Cut every month	1663	393

Cut twice, May to July	1287	275

Cut three times, May to August	1583	337
Cut four times, May to September	1617	347
Cut three times, July to September	2153	428

McConkey concludes, in part: Weekly cutting gives highest percentage protein. Protein percentage decreases and fiber increases with longer rest intervals. The highest per acre yield of dry matter and protein was obtained by resting the pasture until July. The digestion co-efficient of this late cut material has been shown to be somewhat lower than the less mature forage.

The same investigator also cut bluegrass at intervals of 10, 30 and 40 days to determine effect on yield. Results are here given for unfertilized pastures, although fertilized pasture showed the same relative response.

10 days	1513 pounds)	
30 days	1680 pounds)	Total Yield
40 days	1967 pounds)	

The data show that there is a progressive increase in yield of dry matter and crude protein with longer intervals of rest, although percentage of protein was highest when cut every ten days.

Ellitt and Carrier's findings that the total yield of bluegrass varied inversely with the number of times it was clipped during the growing season, appropriately summarize these various studies.

Experimental evidence indicates that available moisture, soil temperature, soil acidity, soil fertility and closeness and frequency of harvesting are the principal factors which affect bluegrass yield. Any one of these may have a limiting effect, although all other factors are favorable. Therefore, high rainfall or fertile soil cannot overcome the deleterious effects of continued close grazing.

FERTILIZERS, LEGUMES AND BLUEGRASS

Fertilizers are regularly recommended and widely used on northeastern bluegrass pastures to maintain high yields. Under intensive pasture management and perhaps in some phases of range management in the West, consideration has been given to their use.

Brown and Munsell report on the results of nitrogen -- sulphate of ammonia and nitrate of soda -- applications in Connecticut. They conclude that even on soils considerably above average in water holding capacity, only about enough additional grass to pay for the fertilizer was obtained from summer application of nitrogen, 71% from sulphate of ammonia, and 29% from nitrate of soda.

April application was about twice as effective as June or August nitrogen based on total bluegrass yield. The seasonal growth habits of Kentucky bluegrass were modified markedly by nitrogen. The usual zenith of growth, May 16 to June 15, was postponed a month by 56 pounds nitrogen in June, and was changed to August 16 - September 15 by 56 pounds in August. April

nitrogen accentuated the May - June peak. Decreasing the clover with nitrogenous fertilizers resulted in a decrease in the nitrogen in the herbage.

October is the most difficult month for the growth of grasses and fertilization has been of little avail. These investigators assign this to unfavorably cool weather. Other investigators present evidence that length of day is responsible.

Bluegrass herbage cut when two inches high had a consistently higher nitrogen content than when cut 3 or 4 inches high. Height of cutting had more influence than nitrogen fertilizer in changing the nitrogen content of bluegrass. Effectiveness of nitrogen decreased with repeated harvest treatments and increased with increases in height of grass when cut.

Pounds of bluegrass per pound of nitrogen, cut 2" - 8 lb.;
3" - 14 lb.; 4" - 11 lb.; 5" - 17 lb.

Additional pounds of airdry herbage per pound of nitrogen
for 4" cutting: N. applied in April - 16 lbs.; N. applied
in June - 7 lbs.; N. applied in August - 17 lbs.

These results were from 28 lbs. at each application; double applications, 56 lbs., resulted in about the same herbage production per pound of nitrogen.

McConkey's work in Ontario supports the foregoing results. It is of interest, however, that his results show greatest response of bluegrass to fertilizer when the grass is repeatedly clipped short. The following yield figures show the additional yields obtained with nitrogen-phosphate-potash fertilizers over unfertilized pastures for three cutting heights.

<u>Height of Cutting</u>	<u>Increased Yield</u>
3 inches	614 pounds per acre
6 inches	510 pounds per acre
9 inches	473 pounds per acre

He also states: "The addition of calcium on this alkaline soil...tended to depress yield, especially in the first year of application."

In attempting to reconcile Brown's and Munsell's work with that of McConkey, it may be concluded that the greatest responses to fertilizer were obtained when grass was clipped to about 4 or 5 inches.

In two unpublished studies in Colorado, the application of complete fertilizers on unimproved bluegrass range resulted in no perceptible increase in volume of herbage. It is believed low precipitation prevented the fertilizers from becoming available.

Legumes. In Kentucky, bluegrass grown regularly with legumes produced 1045 pounds of dry matter per acre, 17% of which was weeds. Bluegrass grown without legumes produced 371 pounds, 49% of which was weeds.

Johnstone-Wallace reports that early grazing increased white clover in the mixture with bluegrass and that bluegrass benefits more from vigorous growth of white clover than it will suffer from early defoliation.

Archibald, Bennett and Ritchie found in Massachusetts that white Dutch and ladino clover averaged distinctly higher (50% than the grass averages) in nitrogen and appreciably lower in crude fiber. The quality of the forage was thus greatly improved by growing legumes in mixture with bluegrass.

Brown and Munsell report a production of bluegrass of 3216 pounds with ladino clover compared with 2927 pounds without clover but fertilized with 28 pounds N. per acre.

Hughes, in Iowa, experimented with drilling sweet and white clover into bluegrass sod, and concluded that it is possible to greatly increase returns from bluegrass in this way. Yield of herbage was materially increased and protein content was higher. However, returns were actually decreased by use of nitrogenous fertilizer, because the increased vigor of the grass suppressed the growth of clover. Clovers, if present, would provide quantities of forage when bluegrass becomes dry and dormant during the summer.

Whitt suggests that the increase in available calcium under bluegrass favors legumes. He proposes the introduction of sweet clover as an efficient means of raising the nitrogen content of the soil.

In one eastern study, the following 5-year average gains per acre on 2-year old steers are reported.

Bluegrass, no soil treatment, no legumes - 100 lb. gain per A.

Bluegrass and legumes, no soil treatment - 155 lb. gain per A.

Bluegrass and Legumes, lime and phosphate - 185 lb. gain per A.

Fuelleman and Graber point out that in Wisconsin 50 or more years of continued grazing, too early grazing, and excessive utilization resulted in waning fertility and a thinned bluegrass sod. The authors renovated a series of 30 widely distributed pastures through the establishment of deep rooted legumes as alfalfa, sweet clover and red clover in thinned sods by scarifying the bluegrass. Fertility was raised, bluegrass stands were greatly improved, and this encouraged better grazing management and the addition of fertilizer.

The foregoing studies indicate that increased net returns may not materialize from the use of commercial fertilizers, especially on drier sites. On valuable and intensively used western pastures, fertilizer application might be employed to give an initial boost to bluegrass recovery where the sod has been deteriorated. On ranges and in most pastures, the same results can be obtained by discontinuing grazing and resting the bluegrass for a period of two to three years.

The effects of commercial nitrogenous fertilizers are most evident for a period of two to three months. Therefore, increase in herbage production is temporary. However, if application of fertilizer is combined with light grazing, the increased organic mulch accumulation should speed up recovery of deteriorated sod.

The introduction of legumes -- white, yellow sweet, and other clovers or alfalfa -- depending on moisture and other site factors, is a promising method of improving bluegrass. A mixed bluegrass-legume stand produces more forage than bluegrass alone. Especially is this noticeable in summer when bluegrass becomes dormant. There is also an appreciable increase in total protein and nitrogen in the forage. Judicious spring grazing of bluegrass may be necessary to maintain the legumes in the stand.

HOW BLUEGRASS IS UTILIZED

Preference. In Massachusetts, a series of seven grass plots were established. Five cows were turned into the area each morning for a number of days. The cows had free choice and equal access to all seven plots and notes were taken on the proportion of total grazing time on each species plot. The cows were on the plots 105 hours, of which 54 hours were spent in grazing. Following are the results.

<u>Species</u>	<u>Percent of time grazed, of 54 hours total (Weighted average)</u>
Timothy	22.8
Orchardgrass	17.5
Redtop	17.0
Rhode Island Bent	16.1
Sweet Vernal grass	16.0
Kentucky Bluegrass	9.8
Sheep Fescue	.8
	<u>100.0</u>

Presumably, higher crude fiber in Kentucky bluegrass and sheep fescue (Festuca ovina) accounted, at least in part, for low preference for these grasses.

Springfield and Reynolds conducted a similar experiment in New Mexico involving quarter-acre plots of eight grasses. Thirty-one range cattle grazed the area in late August and early September. Orchardgrass and smooth brome made up 26% and 24%, respectively, of the total diet. Kentucky bluegrass was intermediate, constituting only 9% of the diet, but was higher in preference than bluestem wheatgrass or big bluegrass (Poa ampla). The investigators conclude that preference is strongly influenced by the relative succulence of the various species.

Darland and Weaver observe that in Nebraska in early spring, cattle preferred western wheatgrass, bluegrass, sedge, little barley (Hordeum pusillum) and cheatgrass (Bromus tectorum). Wheatgrass was very little

grazed after June 20, until new growth started in September. Bluegrass was too closely grazed except in spring, during the period of rapid growth. It should be observed that the rate of stocking in this experiment - about one acre per yearling for six months - represented extremely severe grazing. However, under this treatment bluegrass was replacing the bluestems and other prairie grasses.

Doran, in reporting on the grazing habits of sheep on summer range, on the Western Slope of Colorado, reports percentage of time spent in feeding on various plants. These percentages may be regarded as indices of preference, although they probably also reflect the relative abundance and availability of the various forage plants.

	Ewes	Lambs
All grasses	19.4%	10.2%
Bluegrass	(1.8)	(0.5)
Weeds (Forbs)	57.7	40.4
Shrubs	22.9	49.4

It is evident that bluegrass was a forage plant of minor importance on summer sheep range so long as palatable and succulent forbs and shrubs were available. On ranges where these preferred plants have been eliminated through heavy grazing, bluegrass is taken readily, so long as it is green.

On western cattle ranges, bluegrass is generally regarded as a choice and highly relished plant. Its rapid early growth attracts cattle to it. Later, any green new growth is grazed and regrazed in preference to the taller native grasses. Sometimes, if bluegrass is grazed short by the middle of June, cattle will turn more readily to the bunch grasses, then in rapid growth, especially on flat or rolling ranges. It has also been noted that on some western ranges, cattle will tend to graze other plants if grazing is deferred until bluegrass is matured, about July 1.

Grazing Pattern - A number of investigators agree that cattle graze bluegrass in patches. This pattern is very characteristic throughout the type. Observations in the West indicate that cattle graze these patches to about a 2-inch stubble on fairly vigorous grass and to a one-inch stubble on short bluegrass and gradually extend the edges outward so that patches tend to become larger under continued grazing. If grazing is sufficiently light during the rapid growth period in spring so that additional growth takes place, this is usually grazed back to the original stubble. As the grazed patches become larger, they gradually merge until the entire area has a mowed appearance except for many small clumps of ungrazed grass immediately around dung. With continued grazing, the grass around dung is gradually taken, but while this occurs, the other areas are regrazed so that stubble becomes shorter. The grass around dung is not grazed shorter than three to five inches except under extreme grazing pressure.

At least three investigators agree that where the grass was grazed sufficiently lightly so that ungrazed patches remained, the grazed patches were sought out and grazed year after year. In this way mulch accumulated on the ungrazed areas and these developed into "roughs" which remained

ungrazed until shortness of the grazed areas forced cattle to utilize them. The grass around dung is ordinarily not grazed, except under very heavy grazing pressure, for at least two years.

If the range is lightly utilized in the spring and cattle are then removed, the grazed patches remain evident throughout the summer as irregular areas of shorter grass. The sharply reduced summer growth rate prevents the grazed patches from attaining later in the season the height of the ungrazed grass.

Under western conditions where the average sheep band on summer range consists of about 1000 ewes with lambs and is under the continual direction of the herder, this patch grazing seldom develops. However, eastern investigators indicate where sheep are unattended under fence in bluegrass pastures, they tend to seek out favored areas and to regrazed these areas repeatedly before utilizing less favored areas.

With heavy stocking, the bluegrass sward can be grazed down to about a 1/2 inch stubble height. This represents the removal of 85% to 95% of the total weight of annual herbage production, depending on the average height of the ungrazed grass. Weaver and Darland report that in Nebraska bluegrass was grazed the first two years to 3" - 1 1/2" stubble from spring to mid-summer and to 1/2 inch after mid-summer. The third year, even the spring grazing was 1 1/2" - 1/2" and after mid-summer the grass was very "closely grazed." Under this treatment, deterioration and weed invasion were rapid.

Utilization. The most common practice among range men is to express utilization in terms of percentage. The weight of the herbage removed is expressed as a percentage of the weight of the entire current growth to ground line. This can be determined by clipping and weighing the stubble remaining after grazing, and clipping and weighing ungrazed plants.

Parker and Glendenning recommend bluegrass utilization limited to 40% of the volume on deteriorating or steep ranges, and 50% on ranges in good condition. They suggest that this will result in a stubble height of 1 1/2 inches (where grazed) with 25% of the flower stalks remaining.

Albee, Klosterman, Burkitt and Olson suggest for bluegrass a minimum stubble height of 2 inches on excellent and good ranges, 2 1/2 inches on fair ranges, and 3 inches on poor ranges in the eastern extremity of South Dakota. In the Black Hills region they recommend a minimum stubble height of 5 inches on excellent and good ranges, 6 inches on fair ranges and 7 1/2 inches on poor ranges for tall and mid-grasses, in which group they include bluegrass. The stubble-height table on a following page indicates that this series of recommended Black Hills stubble heights would convert approximately to 50% - 60% utilization on good ranges, 30% to 40% on fair ranges, and 7% to 45% on poor ranges, depending on prevailing grass heights.

In Colorado, in vigorous, moderately grazed bluegrass with average seed-stalk heights of 18.2 inches, heights at the termination of grazing were 7-9 inches. This represented the average of a series of measurements of stubble in the grazed patches, and ungrazed plants in the roughs. Utilization was computed at 38%. With another method, samples were measured

only in the grazed patches, which gave an average stubble height of 2-2 $\frac{1}{4}$ inches. Several step-point, or paced transects (lines of 100 paces were run and the number of hits in grazed and ungrazed patches were recorded) indicated that about one-third of the area had been grazed and two-thirds were essentially ungrazed. By this method, utilization was computed at 41%. In this study the objective was 50% utilization. By projecting the figures, and assuming that additional grazing would not shorten the existing stubble but would enlarge the grazed patches, it was determined that the desired objective would be obtained when the grazed patches covered 65%-70% of the area, or when 30%-35% of the area was still ungrazed.

On adjacent range, which had been heavily grazed for many years, average seed-stalk heights were 14.9 inches and stubble heights in grazed patches were 1 to 2 inches. Utilization was computed at 70%. It is evident from these figures that there is no straight-line relationship between seed-stalk heights, stubble heights and percentage utilization.

In an attempt to relate various stubble-heights to percentage utilization, two studies will serve as examples. One study (unpublished) was made in the Black Hills by Schwan, where bluegrass of three prevailing average heights was clipped to a series of progressively lower stubble heights. The resultant percentage utilization was then computed for each stubble height. The second study was conducted by Clark, in central Utah, who employed similar techniques. The figures show percentage volume distribution for various heights.

Black Hills				Central Utah		
Bluegrass	Seed-	Seed-	Seed-	Under	Under	Under
Stubble	Stalks 24"	Stalks 16"	Stalks 12"	Spruce	Oak	Aspen
Heights	Leaves 14"	Leaves 10"	Leaves 8"	Brush		
24"	0%					
20	-			0%	0%	
16	3	0%		14	7	
15	-	-		18	9	
14	10	2		22	11	0%
13	-	-		26	13	1
12	15	5	0%	29	15	2
11	-	-	-	33	18	4
10	25	10	2	36	21	7
9	-	-	-	39	24	10
8	35	17	5	44	28	14
7	47	23	7	46	33	18
6	50	30	10	51	38	23
5	57	38	15	56	44	28
4	65	48	25	61	54	34
3	73	68	40	70	62	43
2	80	70	60	82	74	58
1	90	85	80	91	87	77
0	100	100	100	100	100	100

A comparison of the Black Hills and Utah figures reveals some differences in the growth form of bluegrass. The much lower values for stubble heights above 10 inches in the Black Hills study may be explained by the fact that these samples were taken in the fall after seed had dropped and when the heads were light in weight.

A Suggested Bluegrass Utilization Standard. It is evident from the many studies heretofore reported that bluegrass tends to become shorter on the site as a result of repeated close clipping or grazing. The first concern, from the standpoints of rangemanagement and watershed management, must be to use the short bluegrass conservatively enough to allow it to recuperate and increase in vigor, and to increase the mulch layer. This cannot be done if an arbitrary utilization standard, based on a given percentage, is used. If the desired objective were uniformly set at 50% utilization, the Black Hills bluegrasses would be grazed to 6 inches, if tall and vigorous; to about 4 inches, if of medium height; and to $2\frac{1}{2}$ inches, if short. In other words, setting up a single utilization standard in terms of percentage, would permit heavier utilization of weak, unthrifty bluegrass. To overcome this, variable standards might be established, as 60% for the tall grass, 45% for medium grass and 20% for the short grass. This would be achieved when the average height of grazed and ungrazed bluegrass plants is about 4 to 5 inches.

The recognized habits of cattle to regraze the same patches for several years introduces another difficulty. Are these patches grazed too closely to retain good vigor? Is there any advantage to the local type to leave ungrazed areas of varying sizes? Apparently, these questions have not yet been answered. It is well established, however, that bluegrass loses vigor somewhat in proportion to the closeness and frequency of defoliation. It has also been shown that short, weak bluegrass grazed repeatedly to 70% has continued to produce only a very small amount of herbage, while the same type has recovered and has increased in vigor with 55% utilization.

A Suggested Utilization Standard:

Slight
0%-10%

Barely apparent. Grazing may consist of light nibbling of leaves or small localized patches.

Light
10%-30%

A grazing pattern is readily discernible. It may consist of irregular, grazed patches or bands which have been uniformly grazed on preferred areas. More than one-third of the type area is essentially ungrazed.

Moderate
30%-50%

Ordinarily, more than half of the area consists of patches grazed to approximately $2\frac{1}{2}$ inch stubble, if the bluegrass is tall and vigorous. If bluegrass is short, the stubble may be only $1\frac{1}{2}$ inches. Grazed patches should not exceed 70% to 80% of the type area. In short bluegrass, at least 30% should be ungrazed.

Heavy
50%-70%

All of the area has been closely grazed except for grass in bogs, under bushes and near trees. Areas in shade of

trees usually lightly used. Grass immediately around dung is ungrazed or lightly grazed, and these small clumps are usually prominent features. Grazing of willows, shrubby cinquefoil, quaking aspen, is usually evident. Frequently, ungrazed weeds as thistle, horse-weed (Erigeron canadense) and others, lend aspect to the scene.

Destructive
70% - 90%

Usually the grass around dung is grazed so that the clumps are short (2" to 3") and conical in appearance, or it may be grazed as closely as the rest of the area. Aside from this, there is no ungrazed grass except in the interior of shrub clumps. Where bluegrass has deteriorated to widely spaced sods, the aspect may be weedy with bluegrass grazed to one inch or less. Very definite destructive use of shrubs and aspen reproduction. Type has a clean swept, or mowed, appearance.

The percentages cited above are intended as general guides only. The lower figures in each class apply to short bluegrass, poor quality range or slopes; the higher figures, to vigorous grass, high quality range on flats.

BIG GAME AND BLUEGRASS

Elk invaded the plots near Estes Park, Colorado, probably in early May. On June 1 the grazing pattern resulting from the elk use in the totally protected plot was clearly evident. This pattern remained visible throughout the summer. Grass continued to be shorter where it had been grazed. By the use of the pellet-group count method, spring elk use was estimated as follows:

Severely grazed range	1½ elk days per acre
Moderately grazed plot	12½ elk days per acre
Protected plot	30 elk days per acre

During the first week in June, 1945 on the San Juan National Forest in Colorado, elk were migrating to their summer ranges. At elevations of 9,000 - 10,000 feet elk were seeking out ridges and steep slopes where new growth on Thurber fescue (F. thurberi) was 8-12 inches. They were making very little use of bottoms and flats, overgrazed in the past by cattle where bluegrass leaves were 2-3 inches in length. In another inspection on the same forest in 1949, elk were using bluegrass extensively in May.

Other observations indicate that elk eat bluegrass very readily throughout the spring and early summer, if the stand is reasonably productive.

Deer. Hill reports that in the Black Hills the ratio of utilization to relative availability is highest (1.24) during the period April to June, and lowest July to September (.10) for grasses. Bluegrass comprised

90% or more of the grasses utilized. Later observations (1950) and pellet-group counts indicated, in the Black Hills, total spring-fall use of the many small bluegrass meadows amounted to about one deer-month per acre under pressure of a fairly large deer population.

Dixon found in California that on March 12 grasses comprised 90% of the deer food. Bluegrass was a preferred species and, with meadow fescue, formed 40% of the forage utilized. Meadow fescue was grazed in preference to bluegrass.

In June, he found that selected deer grazed bluegrass for 13 minutes out of 1218 minutes. At this time many other grasses were preferred. He rates bluegrass palatability "good" and its relative importance "fair."

Julander and Robinette, in unpublished work, report on deer use on summer range in Utah. Where bluegrass was available at 24 lbs. per acre, deer use was 7.2%. On the same ranges, bluebunch wheatgrass (Agropyron spicatum) was available at 28.8 lbs. and use was 3.2%. Sedge (Carex sp.) was available at only 9 lbs. per acre, but use was 10%.

QUALITY OF BLUEGRASS RANGE

Range condition is defined in "Forestry Terminology" as "the state of health or productivity of both soil and forage of a given range, in terms of what it could or should be under normal climate and best practical management." It has become common practice to designate a number (most often five) specific range condition classes.

Most range men regard range condition classes as designated steps in range trend and, therefore, somewhat comparable to stages of plant succession. From this view, the climax community, or at least a relatively stable and enduring type, becomes the unit to which a given series of condition classes are applied. Pickford, as well as Costello and Schwan, regard bluegrass as an invader which becomes abundant in lower successional stages and, therefore, indicates deterioration of the particular type.

However, as pointed out previously, bluegrass itself, although a replacement of other vegetation, may represent a long-enduring type with wide degrees of variation, both in the relative state of health and in productivity. Local site factors may determine the health or productivity of a bluegrass stand compared with an optimum in good sites, and the intensity of grazing may cause wide variations in health or productivity.

It is desirable, therefore, to set up standards for bluegrass ranges for the guidance of range managers. These guides recognize five general criteria which have been widely used for condition classes in other vegetation. These are - composition, density, vigor, mulch, and soils and erosion. In bluegrass, density is generally the least reliable criterion since, on some sites, it decreases where the grass becomes tall in the good and excellent classes. The densities given below should only be used after giving full recognition to the other four criteria.

Since the exact scope of the term "range condition" has not been defined, the term "range quality" is here used to avoid confusion, especially if "range condition" is regarded as more or less analogous to retrogression from the climax.

1. Very Good Quality

Composition - varying from pure bluegrass to a combination of bluegrass and bunchgrasses, as wheatgrasses, fescues, bluestems, tufted hairgrass, Canada reedgrass, or others in higher successional stages or climax, which may be invading and reasserting dominance. Low value plants as dandelions, silver cinquefoil, trailing fleabane, fringed sage, etc., absent or rare. Where palatable shrubs, as willows along streambanks, should normally occur, these are present.

Density - At least 40% by step-point method (Costello and Schwan) and most commonly 60% or more. Total annual production airdry weight 2000 pounds, or more, per acre, based on average production.

Vigor - Seedstalks 24" to 30", or more, when fully developed. Associated palatable shrubs vigorous, no die-back, high-lining, hedging or "sheaf-of-wheat" shapes.

Mulch - Deep and continuous.

Soils and Erosion - No erosion, either in the type or on adjacent slopes. No channeling or bank cutting.

2. Good Quality

Composition - Essentially as under "very good" but there may be a moderate number of plants of lower value as asters, fringed sage, etc.

Density - 40% and up to 60%. Airdry weight average annual production of grasses 1200 to 2000 pounds per acre.

Vigor - Seedstalks 20" to 24". Palatable shrubs, if damaged, must show active recovery. Browse health, vigorous, and reproducing.

Mulch - A deep, continuous mulch layer.

Soils and Erosion - No erosion, no rills, no channeling.

3. Fair Quality

Composition - May contain some weeds as dandelion, yarrow,

or cinquefoil, or shrubs, as fringed sagebrush or others, but less than 20% density by the step-point method. Silver sagebrush (A. cana) may be invading edges of bluegrass type.

Density - Grass density from 20% to 40%. Average annual weight production of grasses, air-dry 600 to 1200 pounds per acre.

Vigor - Seedstalk heights 16" to 20" when fully developed. Height may vary, with taller grass in "roughs" around dung, and in brush patches. Usually, some browse high-lining.

Mulch - Spotty. Mulch is deep in "roughs" but may be light, or nearly absent in favored grazing areas.

Soils and Erosion - In this class, erosion may be absent, or it may consist of slight, local damage on adjacent hillsides, or some raw banks on drainages. Very seldom any erosion in the bluegrass proper. If erosion exceeds "slight," type must be given a lower classification.

4. Poor Quality

Composition - Usually a weedy aspect. Weeds may consist of thistles, low cinquefoils, fringed sage, dandelion, yarrow, and similar species, or grasses like cheat, crabgrass (Digitaria), Tumblegrass (Schedonardus paniculatus), stinkgrass (Eragrostis cilianensis), and others. Shrubs like shrubby cinquefoil, fringed sage, silver sagebrush, rabbit-brush, may be present in the cover. Another condition is where a more uniform mixture of bluegrass and very short weeds or white clover occur.

Density - Usually, the perennial grass density is less than 20%. Ordinarily, one-fourth to one-half the total density consists of inferior weeds and shrubs. Bluegrass production, 300 to 600 pounds per acre air-dry.

Vigor - Aspen reproduction and shrubs, like shrubby cinquefoil and willows, are usually damaged by browsing. Seedstalks usually less than 16" and leaves ordinarily short and mostly mat-like. Nearby willows, aspen and desirable browse damaged and reproduction lacking.

Mulch - Either a very light continuous mulch or an open, spotty layer with much bare ground (up to 50%) exposed.

Soils and Erosion - Varies from no erosion to moderate gully-ing or sheet erosion, especially adjacent to bluegrass areas, although occasionally small gullies may cut through the type. Channel and bank damage none to moderate.

5. Very Poor Quality

Composition - Essentially as for "poor," but inferior weeds, grasses, and shrubs more abundant. The aspect is weedy or shrubby.

Density - Ordinarily, bluegrass is reduced to separate islands of sod. Perennial grass density often about 10%. Annual production of perennial grass herbage 300 pounds, or less.

Vigor - Seedstalks less than 12". Bluegrass very short, matted, weak. Desirable browse damaged or entirely killed out.

Mulch - More than 50% of ground surface bare.

Soils and Erosion - Erosion varies from none to severe with extensive gullyng. Usually, downstream channels show moderate to severe scouring, bank damage, or silt deposits.

An Appraisal of Bluegrass as a Forage Plant

As pointed out in the opening paragraphs, there has been much disagreement on the value of bluegrass. The conclusion, after analyzing research results, must be that bluegrass has desirable, as well as undesirable, attributes. These may be listed as follows:

Desirable Qualities

1. It begins growth earlier than many native grasses and spring volume accumulation is rapid.
2. Under very favorable soil and moisture conditions, such as the deep soils of meadows and parks, the usable volume may be as great as for native grasses.
3. It is palatable and readily eaten by livestock, especially in spring and early summer.
4. Its nutritive value is high.
5. It forms a dense sward which is resistant to incipient sheet erosion within the type.
6. It is aggressive and rapidly colonizes depleted areas.
7. It commonly occupies key livestock concentration areas, where need for cover is acute.
8. It persists under severe grazing, and recovers rapidly when protected against overgrazing.

Undesirable Qualities

1. In most localities and sites, annual volume production is lower than for other native or adapted introduced grasses, particularly with the usual very close utilization.

2. It becomes dormant or semi-dormant in summer and produces but little additional herbage in fall under western conditions.
3. It "kills out" during severe drought, especially on marginal sites.
4. Forage production is low during dry years when most needed.
5. It has a shallow root system, and gullies, once started, cut rapidly into the sub-stratum. Advanced downstream erosion usually meets little resistance to headward cutting in bluegrass.
6. The commonly prevailing pattern of livestock use induces soil compaction, inadequate mulch for soil protection, low infiltration, and high runoff.
7. It is an indicator of range below the optimum or of downward trend for the type and, as such, comes in on suitable sites as result of excessive grazing pressure. It often replaces tree or shrub types as a result of heavy grazing with attendant deterioration of watersheds.
8. Both herbage and roots disintegrate rapidly and appear to be less valuable than other grasses in maintaining organic mulch and good soil conditions.

Objectives in Managing Bluegrass on Western Ranges

A careful appraisal of these attributes forces the conclusion that, although locally valuable, especially for specific purposes such as early forage, bluegrass is inferior to other grasses as a forage plant. It is distinctly less dependable and less desirable for watershed protection than native cover in good condition. These are mostly not faults of bluegrass so much as they are faults of prevailing grazing use which bluegrass seems to invite.

The primary objectives must, then, be to overcome these faults of management. First and foremost, bluegrass must be grazed properly. A reserve of herbage must remain at the termination of grazing to sustain the plant and the soil. With such treatment, it may be expected that on those sites where conditions are not optimum for bluegrass, especially sites which are either too wet or too dry, normal plant succession will result in the reestablishment of adapted native species in the direction of the climax. On intermediate, moist, well drained sites, bluegrass will probably remain an important element of the vegetation for many years.

MANAGEMENT OF LIVESTOCK ON BLUEGRASS

Western ranges on which bluegrass commonly occurs, may be placed in two broad groups. One group includes the prairie and valley ranges and pastures which are flat or rolling. Here, livestock use is relatively uniform and major problems involve seasons and rates of stocking to prevent deterioration, loss of grazing capacity, and damage to soils and watershed. Distribution of livestock can usually be corrected to a reasonable degree by fencing, salting, adequate water development and similar practices. Proper rate of stocking can be controlled by the operator.

The other group comprises the mountain ranges with rougher topography, where livestock, especially cattle, tend to concentrate along creek bottoms, in parks, meadows, flats, and occasionally on flat ridges. Here, the biggest problem is one of livestock distribution. Cattle naturally seek the flat areas, usually near water. Most frequently, stocking rates are not based

exclusively on these preferred "key" areas, but additional stock is placed on the range to utilize the slopes, forage in timber, and isolated parks. Even with the judicious application of management, as riding, salting, and fencing, most often cattle remain in the key areas until the forage is utilized to the extent that plants and soil are damaged.

In a study of a typical mountain range near Estes Park, Colorado, forage was utilized 72% in a small park near water, surrounded by open timber and with an abundance of forage on nearby, rough, steep slopes. In 1949, cow-months' use on the range as a whole was reduced 50%. Utilization at the end of the season was estimated at 70% in the small park. The much smaller number of cattle remained on this preferred key area until the available forage became very short. This is a common situation.

Problems on sheep ranges are less difficult because sheep are under the direction of a herder on most ranges. With careless management, however, concentration occurs near camps, at water, or in easily herded flats. This tendency for livestock to remain on preferred areas has resulted, in many places, in local overgrazing, the killing out of native species, and their replacement with bluegrass.

While the key areas are generally small and often comprise only 5% to 10% of the range, they are high-risk areas from the standpoint of watershed management. Because of the tendency toward excessive use, these are the focal spots for erosion. These are the places of origin for many gullies. As the range is destroyed locally, livestock pressure is transferred on a diminishing range. Thus, the gully system expands unless prompt action is taken.

In any system of grazing on western ranges, the importance of watersheds cannot be ignored.

Season of Use - There is widespread agreement that bluegrass is well adapted for spring grazing. Its rapid early growth and high nutritive value favor spring use. The ability of this plant to become matted and to maintain a good photosynthetic surface close to the ground, its tendency to spread by means of rhizomes, and its ability to replenish food reserves during the late summer, all favor spring grazing.

If bluegrass is grazed in the spring, three management practices should be observed: (1) Grazing should not begin until there is a sufficient accumulation of new herbage so that continuous close cropping can be avoided; (2) To provide opportunity for food storage, areas grazed in spring should not be regrazed in the fall; (3) Livestock should be removed from the area when about one-half of the annual herbage production has been grazed off. Because comparatively little growth is made after about July 1 on western ranges, utilization may be judged at that time.

Fall use is not detrimental to bluegrass if grazing is limited to proper utilization. However, less value is obtained from bluegrass range at this time.

Season-long grazing is the most common practice on most western ranges and pastures. The problem here is to prevent continuous regrazing of bluegrass areas. The amount of bluegrass in relation to native grass range will usually determine management practices. If the bluegrass areas are large and important, or if the range not in bluegrass is steep, brushy, timbered, or otherwise difficult to use, the rate of stocking and length of season will be governed by the bluegrass areas. Grazing should cease when these are properly utilized. Management should aim at better use of the range as a whole without sacrificing or overutilizing the bluegrass.

Mountain ranges on which bluegrass areas are small and provide only a small percentage of the usable forage, present some of the most difficult problems in western range management. No specific guides can be laid down because the problem varies from range to range. However, in each case, use of the bluegrass must be restricted, through available management devices, to prevent excessive runoff, erosion, and the destruction of these areas.

Opening Date - Dry bluegrass remaining on the range in spring has low nutritive values. The protein level (4%-5%) is only about one-half of the minimum required for satisfactory maintenance of mature animals. This dead herbage also forms the current addition to the mulch layer. Consequently, it is inadvisable to turn livestock out early in the spring and expect them to thrive and not harm the range before adequate new growth is available.

Grazing should not begin until spring snow melt is over and the soil is firm and not subject to excessive compaction and sod-cutting.

Johnstone-Wallace suggests that, in New York State, grazing may begin when bluegrass has attained a height of about four inches. Utilization thereafter should be of such an intensity as to maintain a uniform sward and avoid patch grazing. Other investigators point out that close spring grazing is detrimental to the sod, promotes invasion of undesirable weeds, and **weakens** the individual plants. Informal, unpublished studies in Colorado indicate that bluegrass panicles are open when commonly associated species, such as western wheatgrass and the mountain bunchgrasses, are ready to graze. When the panicles are open, bluegrass volume production amounts to one-half to three-fourths of the rapid, early herbage production. Thus, there is a reasonable accumulation of nutritious new growth available if livestock is turned out at that time. The available data indicate that "panicles open" is a good guide to control the opening of the grazing season on ranges where bluegrass is dominant or is a key plant. Data from several western clipping studies indicate that panicles open on about the same date, regardless of the vigor of the grass. Near Estes Park, Colorado, heavily grazed, moderately grazed, and ungrazed bluegrass, in 1949, heights were about 4, 6 and 8 inches, respectively, on June 1. Yet the panicles were emerging uniformly on the three series of plots.

Seedstalks were measured over a six-year period in this same study. Following are average heights for series of measurements made on or about June 1 each year:

	<u>1945</u>	<u>1946</u>	<u>1947</u>	<u>1948</u>	<u>1949</u>	<u>1950</u>	<u>Average</u>
Heavily grazed	2.0"	1.2"	2.4"	3.4"	3.9"	2.6"	2.6"
Moderately grazed	3.8	4.0	4.7	5.2	5.6	3.7	4.5
Ungrazed	5.0	7.2	6.0	7.0	7.7	5.2	6.4

During several years it was considered that the moderately grazed range was not quite ready to be grazed on June 1. An average seedstalk height of 6 inches is, therefore, suggested as a reasonable standard to indicate range readiness of bluegrass on Colorado ranges. With such a standard the heavily grazed range would have been deferred until about June 10 to 15 with anticipated important benefits resulting in better vigor. The average opening date on the moderately grazed range would have been about June 5.

There is a large difference in volume production on the same date in spring on heavily and moderately grazed ranges, as indicated by the heights noted above. Thus, moderately grazed range will have the same amount of accumulated new growth from one to two weeks earlier than heavily grazed range. On a given date in the spring, therefore, there will be a much larger amount of herbage on moderately used range to provide a reserve to carry livestock on into the summer when growth and volume accumulation declines sharply. (Fig. 1).

On ranges where bluegrass areas are small in relation to the rest of the range, subject to livestock concentration and damage and where grazing can be deferred, an opening date corresponding with seed maturity, or about July 1 on average western mountain ranges, may be advisable. It has been shown that there is no loss in protein yield if harvesting is delayed to this point. The increase in fiber and decreased succulence makes the bluegrass areas less attractive to cattle. The tendency for livestock to "camp" on bluegrass flats can often be avoided by means of a late opening date and better use of the entire range can be obtained.

Closing date - One study cited earlier indicates that on October 1 protein content had dropped to the point where it would barely maintain mature cattle. This point probably varies on different ranges and, undoubtedly, is also influenced by weather. Under average conditions throughout the bluegrass belt, however, it is doubtful if it is good business to extend the grazing season beyond October 1. Grazing should, of course, be terminated at any time when the current utilization exceeds the standards cited in a foregoing section.

Rotation Grazing - is recommended by several authors. In irrigated pasture, especially if legumes are mixed with the bluegrass, a two-pasture system is often used. One pasture is grazed for ten days or two weeks, while water is applied to the other and growth is allowed to accumulated. Under unirrigated western range conditions, it is doubtful if such a system of rotation is practical because of the amount of work involved and because of the normal summer dormancy of bluegrass.

It has been shown that bluegrass vigor may increase noticeably after one season's rest. Consequently, rotation systems contemplating alternate use and rest, or spring use alternated with fall use, during succeeding years, may be desirable. A system contemplating complete non-grazing every third or fourth year should prove valuable in restoring bluegrass vigor.

Grazing Capacity. In attempting to establish rate-of-stocking figures, a number of eastern studies, western range survey data, and known volume production and animal nutritional requirements furnish a broad guide, when correlated with desirable utilization standards. Additional conclusions may be drawn from the studies by Weaver and associates in Nebraska, by L. C. Anderson's unpublished studies in the Black Hills, and by data from the plots near Estes Park (Schwan, et al).

In Nebraska, a rate of stocking of 6 cow months per acre has been reported. Bluegrass was severely injured under such treatment. Bluegrass and Dutch white clover, under irrigation in the West, have been grazed at the rate of four months per acre. In the Black Hills, without irrigation, use at this rate resulted in retrogression and damage to the sod. At Estes Park, the intensity of grazing was increased from approximately $1/5$ cow months to about $2/3$ cow months per acre under controlled grazing, and the range improved gradually. Costello and Schwan recognized bluegrass as a component of meadows and of the short grass stage in ponderosa pine ranges in Colorado. A variable rate of stocking from $1/2$ to 1 cow month per acre for meadows and $1/2$ to $1/3$ cow month per acre for short grass in excellent condition down to $1/8$ to $1/15$ cow month for poor condition range is recommended.

The sharp response of bluegrass to weather conditions has been pointed out. Therefore, a high rate of stocking during favorable weather may prove disastrous if continued during drought. A lighter rate of stocking during favorable seasons will provide drought insurance in the form of increased vigor and mulch, and will make adjustments during drought less difficult. For these reasons stocking rates in excess of 1 cow month per acre are not recommended for unirrigated western bluegrass range which is not closely controlled by fence or otherwise subject to intensive good management. The following stocking rates are suggested.

Very good quality - 1 cow month per acre
Good quality - - - $1/2$ to 1 cow month per acre
Fair quality - - - $1/5$ to $1/2$ cow month per acre
Poor quality - - - $1/8$ to $1/5$ cow month per acre

Very poor quality - should not be grazed, but should be rested until it meets the requirements for at least poor quality. Allowing additional recovery to fair or good quality before grazing it is preferable.

SUMMARY AND CONCLUSIONS

Kentucky bluegrass, considered to be the world's most important pasture grass, may or may not be an introduced species in North America.

Bluegrass is a northern species and grows best at soil temperatures of about 65° F. When soil temperatures exceed 80° growth declines sharply. It finds optimum conditions in the Northeast in the 30 to 45 inch annual precipitation belt. April-May-June is the critical period for growth. In the western United States, bluegrass thrives if about 2 inches of precipitation per month falls during this spring period, although total annual precipitation may only be 18 to 20 inches. Bluegrass prefers fine textured soils, nearly neutral and with high nitrogen content. It avoids dry sandy soils and saturated lowlands. It is intolerant of dense shade and length of day is an important influence.

The most important enemies of bluegrass are white grubs (larvae of the June beetle) two true bugs, grasshoppers and pocket gophers.

Bluegrass assumes a short growth form under heavy grazing, and it is most conveniently grouped with the short grasses because of its habit of growth. It grows very rapidly in early spring, and normally forms seed in late June. Later it becomes dormant or semi-dormant, but makes some additional growth in late August or September, if soil temperatures and moisture conditions are favorable. Cessation of growth in October is a response to the short daylight period. Continued close grazing causes a sharp decline in annual herbage production, and particularly in summer growth. Bluegrass is widely recognized for its low annual herbage yields compared with other pasture and range grasses. Yields decline very rapidly under heavy grazing but also improve quickly when grazing pressure is relieved.

Establishment of a stand through seeding is often difficult because of very poor seedling survival. Stands are established principally through rhizome growth. Rhizome extension occurs in spring and fall. Bluegrass roots and herbage decay very rapidly compared with other range and pasture grasses. It grows best in pure stands and suffers from harmful root interactions when grown with other species. It is a shallow rooted grass.

Bluegrass requires more water when in a vigorous growing condition than when clipped short. However, the closely clipped grass requires more water to produce a given amount of herbage. Soil moisture losses from evaporation on short open stands may more than offset increased transpiration loss from vigorous dense swards. A good mulch is an important item in maintaining high herbage production.

From a plant succession standpoint, bluegrass is an invader which occupies a site where climate is favorable when other vegetation is killed or weakened by heavy grazing. Characteristic examples are hardwood stands, prairie grassland, and western mountain bottomlands. The presence of bluegrass is considered an indicator of deteriorated range condition or

downward trend. Close spring grazing or continued heavy grazing, particularly if accompanied by drought, results in degeneration of bluegrass sod and a final very poor weed stage. With the release of grazing pressure, bluegrass recovers rapidly and forms a persistent sod, which, however, gives way eventually, first to secondary species and then to the climax. This successional process is most rapid on sites with prevailing soil moisture either above or below the optimum for bluegrass. Bluegrass is not regarded as an indication of range improvement, since it comes in while succession is away from the climax, and ordinarily not when the range is in process of recovery. Where bluegrass has replaced deciduous trees and shrubs, forage production is frequently increased, but it is considered that watershed values are damaged.

A number of studies indicate that bluegrass in itself, without the influence of grazing, is less efficient in maintaining high infiltration rates than many other species, particularly climax bunchgrasses. Close clipping of bluegrass results in high soil surface density. Trampling is regarded as increasing soil compaction. However, even closely grazed bluegrass resists soil erosion, if the sward is continuous. Close cropping sharply increases rates of runoff, resulting in downstream cutting and gullying. Headward gully extension usually progresses rapidly in bluegrass because of the shallow root system.

Bluegrass has high nutritive values, and percentage of protein is characteristically high. However, because of prevailing low herbage yields, the yield of protein, in pounds per acre, is generally lower than for other pasture grasses. The presence of legumes increases nutritive value of bluegrass range. The nutritive value of dry bluegrass herbage is ordinarily well below the minimum maintenance requirements of livestock.

Bluegrass herbage yields may equal the annual production of bunchgrass ranges under heavy or moderate grazing, but at the expense of watershed health. In Nebraska, replacement of native prairie grasses by bluegrass as a result of heavy grazing is estimated to result in a 35% reduction in average annual forage production. The total yield of bluegrass varies inversely with the number of times it is clipped. Conclusions drawn from a series of studies are that yield also is usually inversely proportional to the closeness of clipping. Effects of severe harvest treatments seem to result in a cumulative decrease in root and herbage weights over a period of years.

It is doubtful if the application of commercial fertilizer is economically advisable under western range or pasture conditions. Fertilizer appears to be more effective when bluegrass is harvested to an intermediate stubble height of 4 to 5 inches than when stubble height is shorter or longer. The addition of legumes to a bluegrass stand is widely advocated in the East, and results in better fertility, increased yields and increased beef production per acre.

One eastern study indicates that where site and accessibility were not factors, bluegrass was less relished by cattle than other common pasture grasses. This suggests that on western mountain ranges, the typical bluegrass site, rather than the grass itself, attracts cattle and results in concentrations and overutilization. Relishability of bluegrass on one Colorado sheep range was found to be low.

Cattle characteristically graze bluegrass to a short stubble in patches. Sheep follow a similar pattern under fenced pasture condition. These patches are gradually enlarged until, under heavy grazing a clean-swept or mowed appearance results. A number of investigators recommend utilization standards of about 50% on western ranges in good condition and readily accessible, about 40% on fair ranges, and 40%, or less, on poor or rough ranges. Such a variable standard could be achieved with a 4 to 5 inch average stubble height. A standard for field use is suggested, moderate or proper use being attained when one-third to one-fifth of the accessible area is essentially ungrazed.

Bluegrass is readily grazed by deer and elk in the spring.

Five degrees of quality are suggested for rating the relative productivity of bluegrass ranges. Very good quality bluegrass range varies from pure bluegrass to a mixture of bluegrass and bunchgrasses, producing 2000 pounds or more air-dry herbage per year with high vigor, deep, continuous mulch, and no accelerated erosion.

Good quality range has a small amount of inferior species, produces 1200 to 2000 pounds per acre, plants are somewhat shorter, mulch and erosion as under "very good."

Fair quality range may have up to 20% density of inferior species, annual herbage yields of 600 to 1200 pounds, shorter plants and lighter mulch. Erosion may be absent or slight.

Poor quality range has a weedy aspect, lower grass density, annual yields of 300 to 600 pounds, low vigor, noticeable damage to shrubs, light, open mulch, and erosion varying from none to moderate.

Very poor quality ranges are weedy or shrubby, density is light, grass herbage yield is less than 300 pounds, more than 50% of the ground surface is bare and erosion may vary from none to severe.

Eight desirable attributes of bluegrass are recognized -

1. Early spring growth is rapid.
2. On very favorable sites volume production may be satisfactory.
3. It is a palatable grass in spring when growth is rapid.
4. Nutritive value is high.
5. It resists incipient erosion.
6. It rapidly colonizes depleted areas.
7. It covers key areas, where a resistant cover is needed.
8. It persists under severe grazing, and recovers rapidly if managed properly.

Eight other attributes are considered undesirable -

1. On most sites volume production is low.
2. It becomes dormant in early summer.
3. It "kills out" easily in drought.
4. Forage production is low in dry years when most needed.

5. It provides poor protection against gullying because of its shallow roots.
6. Infiltration under bluegrass commonly is low.
7. It is an indicator of a deteriorated range or downward trend.
8. Decomposition of roots and herbage is rapid and it does not maintain good soil conditions as well as other grasses.

It is suggested that proper and desirable land and range management will be achieved if bluegrass is properly grazed. Fairly good watershed protection and reasonably high forage yields will be achieved, although these benefits may increase as the type moves toward the climax under continuing proper use.

On rough mountain ranges, bluegrass must be properly grazed on key areas, even though these represent a small fraction of the entire range. To do otherwise invites erosion on these critical areas. Bluegrass is well adapted to spring grazing, but if it is grazed in the spring, it should be rested in summer and fall. Rotation grazing may offer advantages on some pastures or ranges. Vegetative readiness, or the proper opening date for the summer grazing season may be determined by the use of standards when seed stalks are 6 inches in height or when panicles are open. Closing date in fall should be set early enough so as to avoid sharp drop-off in protein content, which occurs in October on many ranges. Continuous close grazing is especially detrimental.

The following average stocking rates are recommended for western ranges.

Very good quality - 1 cow month per acre

Good quality - 1/2 to 1 cow month per acre

Fair quality - 1/5 to 1/2 cow month per acre

Poor quality - 1/8 to 1/5 cow month per acre

Very poor quality - complete rest until bluegrass has recovered to the extent that it will be graded poor or, preferably, better.

Selected Bibliography

1. Ahlgren, H. L. Effect of fertilization, cutting treatments and irrigation on yield of forage and chemical composition of the rhizomes of Kentucky bluegrass. Amer. Soc. Agron. Jour. 30:683-91. 1938.
2. Ahlgren, H. L. and O. S. Aamodt. Harmful root interactions as a possible explanation for effects noted between various species of grasses and legumes. Amer. Soc. Agron. Jour. 31:982-5. 1939.
3. Ahlgren, H. L., D. C. Smith, and E. R. Nielsen. Behavior of various selections of Kentucky bluegrass (Poa pratensis L.) when grown as spaced plants and in mass seedings. Amer. Soc. Agron. Jour. 37:268-81. 1945.
4. Albee, Leslie R., Earle K. Klosterman, William H. Burkitt, and Harlan R. Olson, South Dakota grasslands. So. Dak. Agr. Exp. Sta. March, 1948.

5. Anderson, K. L. Tame pastures in Kansas. Kansas Agr. Exp. Sta. Circ. 206. 1941.
6. Anderson, W. A. Progress in the regeneration of the prairie at the Iowa Lakeside Laboratory. Iowa Acad. Sci. Proc. 43:87-93. 1936.
7. Archibald, J. G., E. Bennett and W. S. Ritchie. The composition and palatability of some common grasses. Jour. Agr. Res. 66:341-7. 1943.
8. Bates, G. H. Life forms of pasture plants in relation to treading. Jour. Ecology. 26:452-4. 1938.
9. Bird, J. N. Stage of Cutting Studies: I Grasses. Amer. Soc. Agron. Jour. 35:845-61. 1943.
10. Brown, B. A. and R. I. Munsell. An evaluation of Kentucky bluegrass. Amer. Soc. Agron. Jour. 37:359-67. 1945.
11. Brown, B. A. and R. I. Munsell. Pasture investigations. 8th report. Modifying the seasonal growth habits of grass. Conn. (Starrs) Agr. Exp. Sta. Bul. 209. 1936.
12. Brown, E. Marion. Seasonal variations in the growth and chemical composition of Kentucky bluegrass. Mo. Agr. Expt. Sta. Res. Bul. 360. 1943.
13. Brown, E. Marion. Some effects of temperature on the growth and chemical composition of certain pasture grasses. Mo. Agr. Exp. Sta. Res. Bul. 299. 1939.
14. Carrier, Lyman, and K. S. Bort. The history of Kentucky bluegrass and white clover in the United States. Amer. Soc. Agron. Jour. 8:4. 1916.
15. Carroll, J. C. Atmospheric drought tests of some pasture and turf grasses. Amer. Soc. Agron. Jour. 35:77-9. 1943.
16. Carroll, J. C. Effect of drought, temperature and nitrogen on turf grasses. Plant Physiol. 18:19-36. 1943.
17. Carroll, J. C. and F. A. Welton. Effect of heavy and late applications of nitrogenous fertilizers on the cold resistance of Kentucky bluegrass. Plant Physiol. 14:297:308. 1939.
18. Clark, Ira. Variability in growth characteristics of forage plants on summer range in central Utah. Jour. For. 43:273-83. 1945.
19. Costello, D. F. and H. E. Schwan. Conditions and trends on Ponderosa Pine ranges in Colorado. U. S. For. Serv. Denver. 1946 (Mimeo).
20. Darland, R. W. and J. E. Weaver. Yields and consumption of forage in three pasture-types: an ecological analysis. Neb. Univ. Cons. and Surv. Div. Conserv. Bul. 27. 1945.

21. Darrow, R. A. Effects of soil temperature, pH, and nitrogen nutrition on the development of *Poa pratensis*. Bot. Gaz. 101:109-27. 1939.
22. Diller, O. D. The forage cover in heavily grazed farm woods of northern Indiana. Am. Soc. Agron. Jrl. 29:924-33. 1937.
23. Dixon, Joseph S. A study of the life history and food habits of mule deer in California. Calif. Fish and Game. Vol. 20. No. 354.
24. Doran, C. W. Activities and grazing habits of sheep on summer ranges. Jour. For. 41:253-8. 1943.
25. Duley, F. L. and C. E. Domingo. Effect of grass on intake of water. Univ. of Neb. Ag. Exp. Sta. Res. Bul. 159. Apr. 1949.
26. Ellitt, W. B. and E. L. Carrier. The effect of frequent clipping on total yield and composition of grasses. Am. Soc. Agron. Jour. 7:85-87. 1915.
27. Evans, M. W. and J. M. Watkins. The growth of Kentucky bluegrass and of Canada bluegrass in late spring and in autumn as affected by the length of day. Amer. Soc. Agron. Jour. 31:767-74. 1939.
28. Forestry Terminology. Soc. Am. For. Washington, D. C. 1944.
29. Free, G. R. A comparison of soil moisture under continuous corn and bluegrass sod. Am. Soc. Agron. Jour. 28:359-63. 1936.
30. Fuelleman, R. F. and W. L. Burlison. Pasture yields and consumption under grazing conditions. Am. Soc. Agron. Jour. 31:399-412. 1939.
31. Fuelleman, R. F. and L. F. Graber, Renovation and its effect on the populations of weeds in pastures. Am. Soc. Agron. Jour. 30:616-23. 1938.
32. Gard, L. E., R. P. Fuelleman, C. A. Van Doren, and W. G. Kammlade. Runoff from pasture land as affected by soil treatment and grazing management and its relationship to botanical and chemical composition and sheep production. Am. Soc. Agron. Jrl. 35:332-47. 1943.
33. Graber, L. F. Competitive efficiency and productivity of bluegrass. Am. Soc. Agron. Jour. 25:328-33. 1933.
34. Harrison, C. M. and C. W. Hodgson. Response of certain perennial grasses to cutting treatments. Am. Soc. Agron. Jour. 31:418-30. 1939.
35. Hartwig, H. B. Relationship between some soil measurements and the incidence of the two common Poas. Am. Soc. Agron. Jour. 30:347-61. 1938.
36. Hein, Mason A. and Paul R. Henson. Comparison of the effect of clipping and grazing treatments on the botanical composition of permanent pasture mixtures. Am. Soc. Agron. Jour. 34:566-73. 1942.

37. Hill, Ralph R. Palatability ratings of Black Hills plants for whitetail deer. Jour. Wildlife Man. 10:47-54. 1946.
38. Hitchcock, A. S. Manual of Grasses of the United States. U. S. D. A. Misc. Pub. 200. Feb. 1935.
39. Hughes, H. D. Response of *Poa pratensis* L. to different harvest treatments, measured by weight and composition of forage roots. Fourth Int. Grassl. Congr. Gt. Brit. Rpt. Sectional Session 6:447-52 and 456-7. 1937.
40. Jewett, H. H. and L. H. Townsend. *Miris dolobratius* (Linn.) and *Amblytylus nasutus* (Kirschbaum), two destructive insect pests of Kentucky bluegrass. Ky. Agr. Exp. Sta. Bul. 508. 1947.
41. Johnstone-Wallace, D. B., J. S. Andrews, and J. Lamb, Jr. The influence of periodic close grazing and pasture fertilization on erosion control. Am. Soc. Agron. Jour. 34:963-74. 1942.
42. Johnstone-Wallace, D. B. The influence of grazing management and plant association on chemical composition of pasture plants. Am. Soc. Agron. Jour. 29:441-55. 1937.
43. Julander, O. Drought resistance in range and pasture grasses. Plant physiol. 20:573-90. 1945.
44. Kennedy, W. K. and M. B. Russell. Relationship of top growth, root growth and apparent specific gravity of the soil under different clipping treatments of a Kentucky bluegrass-wild white clover pasture. Am. Soc. Agron. Jour. 40:535-40. 1948.
45. Koonce, D. High-altitude studies on dry-land grasses and clovers. Colo. Agr. Exp. Sta. Bul. 439. 1937.
46. McConkey, O. Experiments on old bluegrass pasture. Sci. Agr. 21:237-41. 1941.
47. Musgrave, G. W. and G. R. Free. Some factors which modify the rate and total amount of infiltration of field soils. Am. Soc. Agron. Jour. 28:727-39. 1936.
48. Parker, Kenneth W. and George E. Glendenning, General Guide to satisfactory utilization of the principle southwestern range grasses. SW. For. & Range Exp. Sta. Tucson. Res. Note 104. Dec. 1942.
49. Partridge, N. L. Comparative water usage and depth of rooting of some species of grass. Proc. Am. Soc. Hort. Sci. 1941.
50. Peterson, M. L. Effect of method of grazing unimproved Kentucky bluegrass on beef production, botanical composition, and herbage yields. Am. Soc. Agron. Jour. 39:412-22. 1947.

51. Pickford, G. D. Interpreting mountain meadow range conditions by observing trend and stage of plant succession. Northwest Sci. 17:87-90. 1943.
52. Plummer, A. Perry and John M. Finley. Seasonal periods for planting grasses in the subalpine zone of central Utah. Intermountain For. & Range Exp. Sta., For. Serv. Res. Paper 18. February, 1950.
53. Range Plant Handbook, Forest Service, U.S.D.A. 1937.
54. Rydberg, P. A. Flora of the Black Hills of South Dakota. Cont. U. S. Herbarium Vol. III, No. 8, Div. of Bot., U.S.D.A., June, 1896.
55. Rocky Mtn. For. & Range Exp. Sta., For. Serv., Annual Report, 1948.
56. Rocky Mtn. For. & Range Exp. Sta., For. Serv., Annual Report, 1949.
57. Rocky Mtn. For. & Range Exp. Sta., For. Serv., Annual Report, 1950.
58. Schwan, H. E. and Arthur Cramer. Inspection report-Gunnison, U. S. For. Service, Denver, Nov. 9, 1948, Unpublished.
59. Schwan, H. E., Donald J. Hodges and Clayton N. Weaver. Influence of grazing and mulch on forage growth. Jour. Range Man. 2:142-8. 1949.
60. Scribner, F. L. Kentucky bluegrass. Nat. Mag. 26:275-6, 1935.
61. Sprague, V. G. and L. F. Graber. The utilization of water by alfalfa and by bluegrass in relation to managerial treatments. Am. Soc. Agron. Jour. 30:986-97, 1938.
62. Springfield, H. W. and H. G. Reynolds. Grazing preferences of cattle for certain reseeding grasses. Jrl. Range Mgt. 4:83-87. 1951.
63. Stoddard, L. A. and J. E. Greaves. The composition of summer range plants in Utah. Utah Ag. Exp. Sta. Bul. 305, Dec. 1942.
64. U. S. D. A. Year Book of Agr. Climate and Man. 1941.
65. U. S. D. A. Year Book of Agr. Grass. 1948.
66. Watkins, J. M., G. W. Conrey and M. W. Evans. The distribution of Canada bluegrass and Kentucky bluegrass as related to some ecological factors. Am. Soc. Agron. Jour. 33:726-8, 1940.
67. Weaver, J. E. Rate of decomposition of roots and rhizomes of certain range grasses in undisturbed prairie soil. Ecol. 28:221-40. 1947.
68. Weaver, J. E. Role of fire in pasture management. Ecol. 16:651-4, 1935.
69. Weaver, J. E. and F. W. Albertson. Effects of the great drought on the prairies of Iowa, Nebraska and Kansas. Ecol. 17:567-639, 1936.

70. Weaver, J. E. and F. W. Albertson. Major changes in grassland as a result of continued drought. Bot. Gaz. 100:576-91, 1939.
71. Weaver, J. E. and R. W. Darland. Changes in vegetation and production of forage resulting from grazing lowland prairie. Ecol. 29:1-29, 1948.
72. Weaver, J. E. and W. W. Hansen. Regeneration of native mid-western pastures under protection. Neb. Univ. Cons. and Surv. Div. Bul. 23, 1941.
73. Weaver, R. J. Water usage of certain native grasses in prairie and pasture. Ecol. 22:175-192, 1941.
74. Whitt, D. M. The role of bluegrass in the conservation of the soil and its fertility. Soil Sci. Soc. Am. Proc. 6:309-311, 1941.